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U. S. DEPARTMENT OF AGRICULTURE.

Bureau of Plant Industry, Bulletin No....

B. T. Galloway, Chief of Bureau.

Methods of Plant Breeding.

By W. M. Hays, with assistance from
A. Boss, C. P. Bull, and E. C. Parker.

(SEAL)

WASHINGTON.

Government Printing Office.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,

Bureau of Plant Industry,

Washington, D.C. 191

Sir:

I have the honor to transmit herewith, and to recommend for publication as Bulletin No. of the Series of this Bureau, the accompanying manuscript, entitled, "Methods of Plant Breeding".

This paper was prepared by W. M. Hays and those associated with him in the Minnesota Experiment Station, and represents work carried on in cooperation mainly between this Bureau and the Minnesota Experiment Station, and under cooperative relations with the North Dakota, South Dakota, Iowa, and Wisconsin Experiment Stations. Professor W. M. Hays was leader of this work in the Minnesota Experiment Station, where the general scheme of plant breeding organization here outlined was first established. Splendid cooperative relations with each of the State Stations mentioned are now in operation, and there is much progress being made in producing for the farmers of the Middle West crops with power to yield more values per acre. The recommendations of the authors that public plant breeding establishments should be organized on a liberal basis is most heartily indorsed. No other line of public expenditure is proving more profitable than that of creating varieties of our staple crops which yield larger net returns for labor and expenditure required in their production.

Respectfully,

Chief of Bureau.

Hon. James Wilson,

Secretary of Agriculture.

Glossary of Terms.

The following definitions and discussions of terms are given for ready reference, as aids in the perusal of the bulletin, and to serve in bringing the nomenclature of this subject more into harmony with the newer thought and methods in breeding. The reader is urged to refer as often as necessary to these definitions until their use in the text is understood. Especially should every reader master the full meaning and significance of the words: Allelomorphs; broad breeding; character, character pair, clon; dominant; F1, F2, etc., foundation stock; gamete; homozygote; heterozygote; law of recombination; Mendelian; mother plant, mutation theory; narrow breeding; network of descent; number names; nursery stock; open fertilization; P1, P11, Pa, etc., pedigree; proficient, a; recessive; recombination; select, a; seminal; self-fertilization; segregation of characters; unit character; variety, zygote.

Abnormal characters.- Characters which are not well coordinated with the general makeup of the individual and which weaken its ability to thrive in its environment.

Acquired characters.- (a) Characters which are developed during the lifetime of the individual. (b) Characters which, having been in the experience of one or more recent generations, are projected into the progeny through heredity. (Seriously under dispute.)

Allelomorph.- Two Mendelian characters, one of which dominates in the first generation hybrid (F1), while the other is recessive and appears in one-fourth of the individuals of the second generation hybrids, (F2). (See character pair, homozygote, and heterozygote.)

Allogam, or Allogamous variety.- A variety of plants originating from a group of selected interfertilizing individuals, i.e., crossing among themselves, as in corn or cotton. All breeds of live stock are allogamous. (Suggested by Mr. C. S. Scofield.) (See autogam and clon.)

Atavism.- Breeding back, striking back, taking back, reversion. The appearance of characters not in the immediate ancestry.

Autogam, or Autogamous variety.- A variety originated by self-pollination from a single plant; as an autogamous wheat (Minn.No.169) or an autogamous tobacco. (Suggested by Mr. C. S. Scofield.) (See allogam and clon.)

Autogamy.- Self-fertilization, fecundation of a flower by its own pollen.

Artificial self-breeding.- Isolating the flowers of open or insect fertilized plants, which do not pollinate their own stigmas, and artificially pollinating them with their own pollen.

Artificial cross breeding.- In plants, isolating and castrating the flowers of one variety, and applying the pollen, usually by hand, from plants of a related variety.

Artificial hybridizing.- Applying the pollen or spermatozoa of one species to the ovule of another species, with such precaution of emasculation as may be necessary.

Atavism, breeding back, striking back, taking back. Reversion: Partaking of characters of grandparents or of more remote ancestors, not found in the parents. Often the reappearance of recessive characters.

Blood. As used by stockmen, means heredity, or hereditary power; as a blooded horse, a full blood, meaning pedigreed, a pure bred.

Breed.- A recognized group of a species, or of a hybrid between species; a division of a species of animals usually of economic or artistic interest; the Holstein breed of cattle, the Collie breed of dogs, the Berkshire breed of swine. Holds the same place in animal breeding as variety in plant breeding.

Broad breeding.- Allogamous strains and varieties, or breeds, in which in each generation a fairly large number of inter-breeding selected parents are intercrossed in forming the improved network of descent. Thus in breeding corn, if twenty or more centgeners were grown together annually, and from at least ten of the intercrossing rows at least twenty plants were selected for mothers the next year, the breeding would be broad. If, on the other hand, only five centgeners were grown, and if from each of two or three centgeners only five plants were selected for mothers of centgeners the next year this would be rather narrow breeding. (See narrow breeding.)

By.- Used in referring to the male parent. (See Out of.)

Centgener.- Of one birth: (a) The sexual progeny of a self-fertilized plant, as in wheat; (b) of an open pollinated mother plant, as corn; (c) of a plant used as a male parent, as of wheat or corn; (d) of a female animal, as a cow; (e) of a male animal, as a stallion; (f) the parthenogenetic progeny of an animal, as in aphids; or (g) the clonal progeny of plants multiplied by vegetative parts, as the apple.

(The choice of the root word genera is fortunate, of the root word centum unfortunate, as the use of the word centgener cannot be confined to a hundred, but must mean such number, few or many, of a given birth employed in the centgener test, whether of plants or animals, as may conveniently be used to test the breeding efficiency of a parent in the terms of its progeny.

Centgener plat.- One of a series of rectangular or row plots of known dimensions, usually in a plant breeding nursery on which the progeny of a given mother plant is grown in hills, in drills, or broadcast, that the breeding efficiency of the respective parents may be compared, and the best chosen.

Centgener test.- Comparison, usually in small plats or rows, of the progeny of two or more mother plants.

Centgener, seminal.- A test plat where seeds of one mother plant are planted in a centgener plat.

Centgener, clonal.- A test plat where clons of one mother plant are planted in a centgener plat. (See Clon)

Centgener selection.- Comparing the fraternity groups from different parents so as to determine the efficiency along a given line of the blood of the respective parents.

Centgener value, or centgener power.- Projected breeding efficiency; the inherent power of the plant from a single seed to transmit desirable qualities, as measured by the average record performance, as of yield, height, hardiness, of the progeny.

Character.- Unit character. In discussions of heredity this means a transmissable character, as color of eyes in man; size of draft horses; horns or no horns in cattle; form, as in tall and dwarf peas; habit, as in gait of trotting or running horses; strength, as in tough horses and horses

easily tired out; brilliance, as in bright families and dull families of men; ease of fattening, as in beef-bred and wild cattle; milk giving, as in dairy-bred and beef-bred cattle; uniformity, as in variation of corn with ears at uniform height, and corn with rows of kernels of similar form, or as in cattle all of the same color, or hairs all of the same length on the roots of a wheat plant. A hereditary character may be the simplest form or other minute character of some most minute internal part of a cell, on the one hand; or, on the other hand, it may be the entire makeup of the individual, or even the group character of the fraternity group or strain, of the variety, breed or race or of the entire species, genus, order or kingdom.

Character determiner; character bearer, or factor.- The entities which carry unit characters from the father and mother cells through the fused chromosomes of the fecundated cell. (See Factor, Character determiner, Allelemorph, Dominant, Recessive.)

Character pair.- Two opposing Mendelian characters; that is, two characters which pair off; both not showing in the same individual, or but very rarely, only the dominant one appearing in the first generation hybrid and in three-fourths of the second generation hybrids; the recessive appearing in one-fourth of the second generation hybrids and continuing thereafter to follow Mendel's law of segregation.

<u>Chromosomes</u>.- The small organs in and a part of the protoplasmic mass of the cell-nucleus which are thought to contain the character bearers or character determinants, and to divide into two parts, one character of the Mendelian pair going into one "bivalent" and the other in the other bivalent.

<u>Class</u>.- A group of similar things. Can often be used synonoymously with strain, family, variety, etc., or to refer to a collection, as of plants, otherwise stated in the context.

<u>Clon</u>.- A cutting, scion, bud, runner, offshoot, tuber, set, or other part of a parent plant used asexually in making a new plant. (See also autogam and allogam.)

<u>Clonal variety</u>.- A variety made asexually by using clons from a single mother plant. (See Seminal variety.)

<u>Close bred</u>.- An animal or plant tracing back for some generations to a very narrow line of parentage.

<u>Close breeding</u>.- Very narrow breeding, limiting the parentage to a very few interbreeding individuals.

<u>Close fertilized</u>, <u>close pollenated</u>.- Fertilized by pollen of the same floret. (See open fertilized.)

<u>Conjugate</u>.- To join together, as in the union of the two sexes.

<u>Correlation in hybrids</u>.- Where two characters, not apparently with direct physiological relation, are inherited together, as when grape leaves of a given form and fruit of a given flavor go together in the hybrid.

<u>Correlation of parts</u>.- All parts are so related as to work in harmony for a given purpose, as mouth, teeth, stomach, intestines, etc; thus the organs of a cow all work together to utilize rough fodder; while the claws, quick strong limbs, tearing teeth, strong jaws and shorter digestive tract of the lion are adapted to procuring and digesting flesh.

<u>Cross breeding</u>.- Uniting two distinct breeds, or varieties. A distinction between this and hybridizing cannot be strictly drawn. (See Hybridization.)

<u>Crosses, or cross breeds</u>.- The animals or plants resulting from a first cross of distinct breeds or classes of cattle; sometimes used for mixtures of blood in other proportions, as the so-called three-quarter blood cattle produced by using pure bred males of one breed on the half blood females. (See Grades.)

<u>Cross</u>.- The product of crossing parents different yet not so radically different as to be termed a hybrid. (See Hybrid.)

<u>Cryptomeric characters</u>.- (Literally meaning a hidden ~~measure~~ portion.) Characters which are latent or atavic through many generations but finally appear in the progeny. (See Atavism.)

<u>Darwinism</u>.- The doctrine that natural selection has caused the improvement of species and the production of new species.

<u>Dioecious</u>.- Species with the male and female organs on different plants; as in hemp. (See Monecious.)

Dominance.- The quality in a Mendelian character of appearing in any given generation of a hybrid plant or animal at the expense of the alternative character which though present in the germ plasm is kept from appearing; the latter is then said to be "recessive". (See Recessive.)

Dominant, n.- That one of the character pair which decides the appearance of the first generation hybrid and three-fourths of the second generation hybrid, one-third of which, or three-fourths of the whole second generation hybrid, being pure homozygote.

Ear-to-Row Test. Centgener test in which the seeds are taken from a single inflorescence, as an ear of corn, a spike of wheat, a panicle of oats, or a head of clover. (See Centgener test.)

Elementary species.- Those plants in a self pollenated species which are very nearly of one type, presumably the progeny of a very strongly mutating plant some generations back.

Environmental influences- The effect of the surroundings (a) on the individuals of a strain, variety, breed or species; (b) and on the successive generations, operating (b^1) through natural selection, or (b^2) on the internal impulses of the living matter to vary in response to conditions. There is great dispute as to the effect of environment in its operation through heredity, and much research is needed.

Evolution.- The doctrine or the theory that species are mutable, that is, progressively changeable, and that organic life has risen from simple forms to complex forms grouped in species, genera, etc.

Evolution, artificial.- The rapid changes effected in strains, varieties, breeds or species as secured by man with the aid of scientific knowledge and methods of breeding.

Evolution, natural.- The gradual, or in very rare cases the rapid, change, usually progressive, which takes place among native species of plants or animals.

Factor.- Sometimes used as a general name to designate the substance or force within the generative cell which carries a unit character from parent to progeny, of which may lie dormant in one or more generations to come up as a recessive in a near generation or as an atavic character in a remote generation. The potency, the power to survive the vicissitudes of complex struggles through long years of dormant existence in the mature body and in their generative cells, and the oftimes unit character purity of these long dormant factors, are constantly illustrating that these factors are the forces which control in natural evolution and which must be dealt with as his elemental forces by the breeder, as the colors are the elemental materials used by the painter.

Fecundation.- The fusing of the male and female generative cells and the rearrangement within them of the character determinants into a new individual which must pass its prenatal period and its period of separate existence. The pollen grain fertilizes the ovule in plants, and the spermatozoon fertilizes the ovule in the animal.

Fecundity.- The power of producing young, of procreating, usually referring to the female. The fecundity of some breeds of swine is high, that is, the females bring forth large litters.

Fertility.- The power to beget young.

Filial generation.- The sexually produced progeny (a) of a self pollinating plant; (b) of a mother plant open to more or less cross fertilization, with wind and insects by the pollen of various plants; or (c) of a mother plant artificially pollinated from a given plant used as the father might refer also (d) to the progeny of a male bred on one or more female plants. Used also in animals, as (e) the progeny of two parents, or if qualified, (f) as the progeny of a given male or female when bred to more than one of the opposite sex. Also more loosely used as meaning (g) the hybrid progeny when two varieties, breeds and species with Mendelian characters are cross fertilized; thus, F1 stands for first generation hybrids, F2 for second generation hybrids, etc, F meaning filial generation. (See fraternity group.)

First cross.- Usually used in speaking of use of first blooded male in up grading. Animals resulting from a pedigreed animal bred on grades are called first cross animals or "half-blood" grades.

Foundation bed.- The especially planted plat or field from which superior individual plants are chosen to be subjected to centgener tests.

Foundation stock.- (a) A species, variety, or breed, or even a sample of seed of a given variety of plants, or a family of a breed of animals, brought into the work of the breeding establishment from which to select individuals for centgener testing, or to serve as a source of blood in hybridizing or in selective breeding. (b) The network of descent, the blood, the heredity, serving as a part of whole of the basis used in producing an improved variety or breed.

Fraternity group.- Plants or animals with a common parentage on both sides, or on one side; thus the trees of a variety of apples are all in the same clonal fraternity group; the plants in a wheat variety originating from a single self pollinating parent plant are in an autogamous fraternity group; the plants resulting from the careful cross-pollination of two corn plants form a fraternity group with a male and a female parent; the plants from an ear of corn fertilized by pollen from the same and many other plants form a fraternity group with only one parent in common. (See Filial generation.)

Full-blood.- An animal whose blood traces back to the original stock on which the breed was founded, and entitled to registration in the herd book of the breed; not cross-bred and not a grade animal.

Gamete.- A body or "factor" in the generative cell which unites or conjugates with another gamete to form a zygote. (See Zygote and Homozygote.)

Genus.- A collection of related species of plants or animals. Most species will not cross fertilize, though some do in nature and others may be artificially induced to cross fertilize. In the genus Graminae there are many species of grasses, as timothy, orchard grass, etc.

Grades, N.- Product of full blood male on native or grade females, as one-half, one-fourth, one-eighth blood, when stated mathematically. Uniting these we get intermediates between, as a one-fourth blood bred to a one-eighth blood gives a three-sixteenths progeny.

Grade breeding.- Breeding of full blood sires on native females or on the grade product.

Heredity. Hereditary transmission of the physical and psychical qualities of parents to their offspring; the inherent forces which project forward from generation to generation the characters of living things.

Heterogenous.- Having flowers in which the anthers stand at different heights, nearer to or more remote from the stigma, sometimes increasing or decreasing the chances of self-pollination.

Heterozygote.- That part of a fertilized ovum, or other sexual generative cell resulting from the union of two Mendelian gametes, which contain both the dominant and the recessive zygotes of a given character pair. Varieties in which both characters of a Mendelian pair are present are said to be hybrid or impure in relation to that character pair. (See gamete, zygote and homozygote.)

Homozygote.- That part of a fertilized ovum or other sexual generative cell which carries character determinants, resulting from the union of two Mendelian gametes which contain only one kind of determinant; either the dominant or the recessive. Varieties with one or more homozygotic characters are said to be homozygotic in relation to those characters. (See Heterozygote, Zygote and Gamete.)

Hybrid.- A plant, or animal, fraternity group, a strain, a variety, a breed, or a species which is the result of crossing one or more individuals of two different distinct strains, varieties, breeds or species, in any combination, making progeny clearly different from either parent; or more technically speaking, the product of two types which result in the recombination of one or more Mendelian pairs of characters.

Hybridization and Selection.- Making new varieties, breeds, or species by mingling the blood of two or more parent stocks, and from this hybrid used as a foundation stock choosing the very best plants to be used as the clonal parent, the seminal autogamous parent, or the heterogamous parents of further new stocks, thus by selection securing such networks of descent as may best serve the desired purpose as pedigreed varieties or breeds.

Hypostasis.- A character hidden by another character which masks it; as when the black pigment prevents our seeing the red pigment also inherited in hair.

In-and-In Breeding, or Incestuous breeding.- Breeding very close relatives, as first cousins, half brother and sister, double cousins, brother and sister - very narrow breeding, but not as close as self fertilization. (See Outcrossing, Narrow breeding, and Broad breeding.)

In Bred.- The result of breeding animals of close kin to each other, very narrowly bred.

In Crosses.- Crossing within the family of the variety or breed; rather narrow breeding.

Inheritance.- The transmission of mental or physical characters. (See Heredity.)

Intrauterine influence.- Effects on the young during its prenatal life. The popular belief in results arising from shocks or frights to the dam during pregnancy are not well under-

stood; at least their importance and frequency are presumably very much overrated, and it may be fairly assumed that they have relatively small or no practical importance.

Lamarckism.- Rival theory to Darwinism, a theory of evolution, the central idea of which is the development of species, genera, etc, by the inherent efforts of the organism to adapt itself to new conditions.

Latency.- Where a character determiner or factor is present in the generative cells, and does not show, as do most recessives, in the one-fourth of the second generation hybrids; but shows finally, if at all, either rarely or after a lapse of a number of generations. (See recessive and atavism.)

Line breeding.- Breeding rather narrowly as in a family of cattle, or in a family of corn, so that the network of descent traces back to a small group of parents; as in breeding Cruikshank's Shorthorn cattle; but it does not mean very close breeding within the family; not so closely as inbreeding.

Line crosses.- Crosses between closely related individuals, as of a variety, not originating from a single plant, or of a breed of animals.

Mass selection.- Selection of seeds from the field or from the bin. Thus mass selection of rye may be made the first year by grading out and planting large, plump, dense kernels; the

second year the best ears may be chosen and a centgener plant grown fromeach ear and the seeds from the best centgener chosen; the third year the seeds from these chosen centgener plots can be mixed together, and by means of this mass selection of the fanning mill the heaviest seeds can be again secured; superior heads can then be chosen for centgener test plots the fourth year; thus alternating a year of centgener selection and a year of mass selection.

Mendelian.- Unit characters of opposite nature, when brought together in hybrid cells follow law of segregation of hybrids into dominant and recessive unit characters; the dominant only appearing in the first generation hybrid, but in the second generation the recessive character appearing in one-fourth the progeny; discovered by Gregor Mendel.

Mendelian selects.- Term useful in the plant breeding nursery. Individual plants in hybrid stocks in which Mendelian characters are recombined, chosen because in them the desired characters are recombined and because of their general individual excellence.

Mendelian hybrid.- A hybrid in which one or more characters follow Mendel's law of dominance and recessiveness; used usually to mean the unselected hybrid collection of plants used as a foundation stock from which to secure Mendelian select plants and from among these to secure the proficient plants. (See Select (M) and Proficients.)

Mendelian pair.- Two characters, which, when present in a hybrid result in one being dominant, showing, and the other recessive, not showing.

Mendelian variety.- A variety formed by segregating hybrid plants in which two or more homozygotic characters are recombined.

Monobasic variety.- A variety based on one mother-plant by multiplying it by means of vegetative parts, clonally, as in the apple; or by means of self fertilized seeds, seminally, as in wheat. (Suggested by Dr. C.H.Scofield.) (See symbasic.)

Monoecious.- Species with the male and female organs borne on the same plant; as wheat or clover with both in the same floret, or corn with male organs on a different part of the plant.

Mother plant.- The parent of a group of plants, as the mother of a centgener plat or even of a variety of wheat; a mother beet; a mother apple tree, etc. May refer to either a seminal or a clonal mother plant.

Mule.- An infertile cross between species, as between the mare and the ass; or between other species of plants and animals differing so widely that the progeny are infertile.

Mutation.V.- The act or process of change, alteration, variation.

n. The product of a sudden change in a species, variety or breed, usually the product of a single plant or animal which is not only itself individually markedly different

from the foundation stock but projects this difference into its progeny, whether self-pollinated or produced by cross fertilization with the plants or animals of the foundation stock.

Mutation theory.- The theory that species, varieties or breeds mutate not alone by imperceptible steps but also occasionally by sudden large steps, thus resulting in new species, springing full-fledged from the parent species. (Made prominent by the researches of Prof. Hugo de Vries.)

p Mutant.- A plant or animal which (a) is markedly different from the species, variety or breed to which it belongs; (b) has the power to project its peculiar individuality into its progeny; and, if of an open-pollenated species, (c) has the power either to endure very narrow breeding and thus to separately perpetuate the mutating characters.

Native.- (1) A wild animal originally found in the region; (2) a domestic animal, usually a grade raised nearby, as distinguished from an animal shipped in for feeding, milk, work or for slaughter.

Natural breeding.- Breeding from those which as breeders prove to be the best, with little regard for closeness or distance of relationship.

Natural insect breeding.- (a) The planting of varieties, as of clover, near together and allowing bees and other insects to cross pollinate them; (b) to isolate and use insects

under screens to cross the flowers of the variety; (c) to remove all but the best plants so that the insects may cross only these--thus to secure a stock of hybrid seeds from which to select in making varieties.

<u>Natural</u> <u>selection</u>.- The selective operation of external conditions on an organism, as, when cold winters eliminate all but the hardiest clover and alfalfa plants, and among these efficient plants some prove especially efficient in transmitting to their progeny the power to endure succeeding cold winters, thus developing hardier strains.

<u>Network</u> <u>of</u> <u>descent</u>.- The sum of unit characters, and of undiscernable characters, which, when woven together, make up the hereditary forces of that succession of individuals which gives us the species or lesser group of plants or animals, as the breed, variety or strain.

<u>Non-Mendelian</u> <u>characters</u>.- Characters which to a lesser or greater degree depart from the Mendelian laws, or at least, in which the Mendelian plan of inheritance is so mixed in its manifestations as to be, as yet, not well understood.

<u>Number-Names</u>.- Serial numbers given to serve as names, temporarily, as in individual plant numbers and nursery stock numbers in the plant breeding nursery; and permanently, as number-names of varieties, or herd book registry numbers of animals.

<u>Nursery</u> <u>field</u> <u>crop</u> <u>breeding</u>.- Nursery breeding of cereal crops, forage crops, field root crops, fiber crops, etc.

Nursery plant breeding.- The area upon which the breeding work with the individual plants and their immediate progeny in centgener plats is carried on.

Nursery stock.- A group of plants in the nursery, (a) often the progeny of a single mother plant, as of wheat or apple; (b) of a small group of plants, as of corn; or (c) a group of hybrid plants resulting from crossing given varieties of species.

\+ Ontogeny.- The history of the evolution of individual organisms. (See Phylogeny.)

Open-fertilized, or open pollinated.- A species in which at least a part of the stigmas are fertilized by pollen from other plants, usually aided by the wind or by insects. (See Close-fertilized or Self pollinated.)

Out-crosses.- Sometimes used by those breeders of full blood animals who generally bred in line, to designate going out of the family for an occasional dash of blood from another family of the same breed. Thus, N.H.Gentry occasionally tried an outcross on his narrowly bred strain of Berkshires, with an animal secured from a breeder who has another family of Berkshires. Failing to secure from better progeny from the outcross than his line breed strain, he often chose the alternative of retaining the narrowly bred strain with which no outside blood was tried.

Out-crossing.- Breeding to a related family of the breed or variety; as breeding Shorthorn cows of the Bates' family to a Cruickshank bull, or to a family even less distinctly related; or as bringing ears of Reid's Yellow Dent corn long bred by a different breeder into the corn nursery of another breeder of this variety, as under Williams' method, p...., introduced ears designated .... (See In-and-In breeding, Narrow breeding and Broad breeding.)

Out of.- Used in referring to the female parent, in contradistinction of "by" used in referring to the male parent.

Parthenogenesis.- Reproduction by means of unfertilized eggs, seeds, or spores, as in rotifers and polyzoa, production of a new individual from a virgin female without intervention of a male, as in plant lice.

Pedigreed.- The lineage record of animals and plants, supposedly bred from select and proficient parents.

Pedigreed breeding.- The work of creating new values by segregating the clonal or self pollinated progeny of single parents, or groups of interbreeding individuals, which make up a superior network of descent and thus originating groups of animals or plants with superior values.

Phylogeny.- The history of the evolution of organic tribes, varieties and species. (See Ontogeny.)

<u>Place effect</u>.- The changes resulting from taking a variety from one region or environment to another. The variety often responds to the new conditions, as the skin on a man's hands thickens and becomes resistant when he changes from an indoor occupation to rough labor in cold outdoor weather. Sometimes the place effect seems largely to take place the first generation; in other cases it is cumulative. Tests of values per acre in field crops, based on first year experiments often are much less reliable than tests of the second and subsequent years when seeds grown in the new places are used.

<u>Prepotency</u>.- The power of one parent plant or animal to give to the progeny more of its character than comes from the other parent. It is applied within the breed, where Mendelian dominance can not be clearly observed, and its relation to such dominance is not well understood. See Projected efficiency, which broadly covers prepotency as well as the power to project values in self pollinated stocks, where both parents are one. Prepotency includes more than dominance; it includes the coordination of Mendelian characters and non-Mendelian characters, if there be such in the well rounded individual.

<u>Proficients</u>.- Plants selected because of their individual excellence and proven by centgener or other tests to have also high projected efficiency in producing progeny with high average value. Thus that wheat plant proven in centgener tests the most proficient in the 10,000 tested is chosen for the mother of a new variety.

Projected breeding efficiency.- The power of the individual to transmit values of its own and its ancestors into its progeny. Thus, one plant, or animal, may project into its progeny great variation and the power to produce an occasional individual of great value, while another may have the power to project into its progeny very high averages of excellence - the term being usually used in the second sense. (See Prepttency and Proficients.)

Pure Bred.- (a) Much used by stockmen with the same meaning as pedigreed, registered, or entitled to registration; (b) sometimes used to mean homozygote in reference to a single character.

Recessive.- That one of the Mendelian character-pair (a) which sleeps during the first generation hybrid but appears in the one-fourth of the second generation hybrid, and is present and asleep in another half of the second generation hybrid; (b) and which may lie dormant for several generations when its reappearance is designated as a case of atavism or striking back.

Reciprocal crosses.- The jack crossed on the mare produces the mule. The reciprocal cross of the stallion crossed on the jennet produces a hinney. In nearly all cases reciprocal crosses are similar, the case of the larger mule and the smaller hinney being very unusual both in animals and in plants.

Recombination, - Law of. - By hybridizing two varieties each of which has an economically desirable character not possessed by the other, the desired character of one pair may be combined with the desired character of the other pair; and each of these may be secured in homozygote condition, by formal methods of selection, eliminating the two less desirable characters of the two pairs. By hybridizing the hybrid having the newly combined characters with a third variety or species having another desired character, that also may be brought into the combination and may by selection be fixed as a third homozygote character.

Registered. - Recorded in a herd book or registration book, as of a breed of live stock, or a variety of corn. (See registration of corn, p...)

Reversion. - The recurrence of a character which has long been recessive. (See Atavism.)

Rogue. - N. An odd plant among others nearly all alike. V. Selecting out and discarding undesirable forms from a variety; thus roguing out short plants from a variety of flax bred for long fiber.

Scrub. - An inferior animal or plant of unknown, usually mixed, breeding.

Segregation, Mendelian. - In the hybrid reproductive cell each gamete of the first generation hybrid is in two parts. Some dominant determinants unite with dominants making dominant homozygotes; and some recessive determinants unite with

recessives and form recessive homozygotes; and some dominant determinants unite with recessive determinants forming heterozygotes. Since the two classes of determinants in the sperm cell and in the ovum are present in the same number, in the production of first generation hybrids, and each has an equal chance to unite with determinants of its own kind and with determinants of the other character of its pair, there results a half which are mixed or heterozygote, and a half which are unmixed or homozygote. Of the homozygotes half are dominants and half recessives. Thus of the second generation Mendelian hybrids one-fourth are pure dominant, one-fourth recessive, and one-half are hybrid or heterozygote with the dominant showing.

Selection,- (a) Determining the best foundation stocks from the blood of which to segregate the best network of descent; (b) securing from the variety, breed or species or from the hybrid stock those plants or animals with the most highly developed individual excellence in the desired line, here called selects; (c) by centgener tests, finding among many selects those occasional plants with high projected breeding efficiency along the desired line, here called proficients, (d) by variety field tests determining the relative values of clonal and seminal varieties produced often by nursery selection, and of seminal or clonal varieties selected out of hybrid stocks.

Selects, Select plants.- Plants which have been selected out of many with a view (1) to using the seeds or clonal parts of each in a progeny test plot, or (2) to merging them and using the merged seeds as the basis of a strain of the original variety.

Selfed, or Selft.- Same as self pollenation, which see.

Self-fertilization.- The fertilization of the ovule with pollen from the same plant, from another floret on the same plant, or from a floret on a plant of the same clonal variety. (See Self-pollenation, also Open-fertilization.)

Self-Pollenated.- Fertilized with pollen of the same seminal plant.

Stocks.- The identical seeds or plants and their descendants, unchanged by selection or hybridizing, which came from a definite line of breeding, or which was received as an invoice from the outside. (See nursery stock and foundation stock.)

Species.- A group of interbreeding plants or animals which stands out rather clearly in one or more characters from related species. See Genus, which is a group of related species; Variety and Breed, which are divisions of a species.

Sterility.- The inability to beget young. The mule is a sterile hybrid. Disease and advanced age cause sterility.

Strain.- A not well defined term. Often used to mean a subdivision of a variety, usually used in the formative or nursery period when varieties are being made by breeding; the word variety being adopted when a new stock has proven its cultural value and has earned a name under which to be distributed. Use of word nursery stock, as nursery stock No.1; N.S.No.2; etc., often avoids necessity of use of this indefinite term. Growers are thus rarely asked to use or understand any other word than variety, which is quite sufficient in commerce. (See variety and subvariety.)

Seminal variety.- A variety produced by seeds. (See Clonal variety)

Sport.- See Mutation.

Sub-Variety.- A division of a variety. More confusing than useful in commerce, where the word variety, especially is accompanied by both a proper name and a number-name, is quite sufficient. Nursery stock numbers are much more definite in breeding records.

Symbasic.- A variety based on a smaller or larger group of select interbreeding parent plants. Varieties of open pollinated species of plants and breeds of animals are thus symbasic. (Suggested by Mr.C.S.Scofield.) (See monobasic.)

Taking back.- See Atavism.

Top cross.- (a) Using a male from (a) in "outcrossing"; (b) in crossing breeds, as of cattle; and varieties, as of corn, (c) in up-grading by bringing in successive males of a given breed on the herd.

Variety.- A division of a species of plants, usually of economic or artistic interest. This like the word breed in animals, is the one word which growers use; and with the system of proper names and number-names proposed in this bulletin it should be used almost exclusively. The words subvariety and strain can be used in a general way, often expressing relationship to the parent variety and serving to avoid tautological use of the word variety. (See Subvariety and Strain.)

Variety crosses, or Variety hybrids.- Crosses or hybrids between varieties, or sub-varieties. The two terms are often used synonymously, and a sharp and fast definition between them can not be made. (See Hybrid.)

Variation.- Changes in the network of descent of a species or lesser division of plants or animals, which manifest themselves in differences which appear in the individuals and groups of individuals making up the species, variety or breed. Nature makes most of her changes very slowly. Man can produce or segregate variations much more rapidly than would occur in nature.

<u>Variation</u>.- Differences which arise in the form, color or other character of an individual, variety, breed, species or genus, and which may or may not be wholly or in part transmissible through heredity. A sudden variation which is fully transmitted is called a mutation. Variations which are not transmitted are called fluctuating variations.

<u>Vegetative reproduction</u>.- The multiplication of a seminal plant by means of cuttings, buds, tubers, offshoots, or other clonal parts of the parent plant.

<u>Xenogamy</u>,- <u>Cross Fertilization</u>,- The fecundation of the ovules of a flower by pollen from another flower of the same species, or another plant.

<u>Zygote</u>.- A body resulting from the coalescence of two gametes. (See Gamete, Homozygote and Heterozygote.)

Selected Stock. Stock of plants under improvement by selection.

Discards. Plants or stocks discarded during selections.

Selects. Individual plants chosen in nursery trials.

Reserved Animals. Animals in circuit breeding which are designated as eligible for use in breeding in the cooperative circuit.

Circuit Pedigree. The combined lineage and performance record pedigree showing the individual and genetic values of a circuit animal.

Reserved Nursery stocks. Seeds or clonal stocks from mother plants whose progeny have proven among those worthy of further trial

INTRODUCTION.

The leading purposes of this Bulletin are: To make clear the very large profits accruing to the public from intelligent and comprehensive efforts to improve our staple varieties of crops by breeding; to give the general features of a plan under which public and private plant-breeding establishments may be organized; to discuss methods of breeding field crops; to discuss the distribution of pedigreed seeds; to give something of the technique of breeding a number of types of crops; and to give emphasis to the need of further research that methods of breeding plants now in vogue may be improved upon.

The work on which this bulletin is based was organized by W. M. Hays at the Minnesota Experiment Station in 1888 and at the North Dakota Experiment Station in 1892, and subsequently under his leadership, when again in the employ of the Minnesota Experiment Station 1897 to 1904, inclusive. These two stations and the State experiment stations of South Dakota, Iowa, and Wisconsin were brought into cooperation with the Bureau of Plant Industry of the United States Department of Agriculture. During the last several years the cooperation between the Bureau and the respective State experiment stations has been direct. The copy, mostly written by the senior author, has been carefully viséd not only by the other authors, but by numerous other experts in plant breeding.

A chapter is devoted to the general plans and theories of practical breeding, and in the last part of the bulletin these plans and principles are applied in a practical way in statements of

methods suggested respectively for breeding twenty- different crops. These suggestions largely follow the practices long in use in the breeding operations at the Minnesota Experiment Station, with modifications drawn from many sources. This plant-breeding enterprise which began as an adjunct to a project to study animal breeding and to produce improved breeds twenty years ago, followed the philosophy of the animal breeders rather than the philosophy of the plant breeders. Since that time much has transpired to show that plant and animal breeders need the same philosophy; and that there is little more difference between plant and animal breeding than between breeding some species of plants or than between breeding some species of animals. It is manifest that those who desire to project plans for animal breeding commensurate with the problem have much reason to study the breeding of plants, where the use of immense numbers and many formal investigators of heredity are developing and emphasizing leading facts which the animal breeder as well as the plant breeder must respect. And the breeders of animals and those who are making investigations in animal breeding are constantly developing facts of importance to breeders of plants.

The term centgener, devised to crystallize the idea of measuring the breeding power of the parent in the terms of the average values of a group of its progeny, has helped to introduce the more scientific use of records of performance in breeding many classes of plants and animals originally used in the breeding of trotting horses and dairy cattle. Recording the merit of individuals, testing the centgener or genetic powers of selected parents, along with the study and practice of Mendelism, have now become the basic

factors of scientific breeding of plants, animals and men. These investigations had something to do with reducing the practice of creative breeding to a scientific basis.

PROJECTS GROWING OUT OF THESE INVESTIGATIONS.

The theoretical investigations and the practical experience in the breeding of twenty-   species of field crops have led to numerous other plant-breeding projects, and these investigations of plants, having been begun in part to gain a broad knowledge of heredity, of breed and variety formation, and of growing and distributing of pedigreed breeds and varieties are to be given part credit for the bringing together in the American Breeders' Association of the plant men and the animal men, both the practical breeders and the scientists interested in the study of heredity. In part to these investigations were also due the formation of the so-called "circuit" plan of animal breeding, under which the Minnesota and North Dakota Experiment Stations in cooperation with the United States Department of Agriculture, have entered upon projects to originate a strain of "Minnesota Milking Shorthorns" and a strain of "North Dakota Holsteins". Under similar projects are under advisement, especially one for breeding a race of swine adapted to northern conditions, more resistant to disease, with higher fecundity, with a larger percentage of lean meat, greater economy in feeding, and earlier in maturing.

Distinctive features in this bulletin are: (a) Methods of naming and numbering varieties, nursery stocks, and individual plants; (b) methods of record keeping in nursery and field variety testing, in hybridizing and in theoretical investigations of hered-

ity; (c) methods of nursery breeding coupled with the practical methods of testing varieties; and (d) methods of distributing new varieties of field crops.

Experienced breeders of wheat, corn, cotton, flax, and other crops have abundant proof that by breeding ten or even twenty-five percent may be added to the value of our field crops with a relatively small expenditure. The results of work done under plant-breeding establishments supported by public funds is nearly all net profit to the people. And if this bulletin aids in emphasizing to legislators, and to others interested in promoting agriculture, the economic value of this work, and in making clearer the way of the technician, whether private or working under public auspices, who would add to the breeding power of our seeds and plants, the purpose of the authors will be achieved.

THE BREEDER'S CLASSES OF PLANTS.

Several classes of plants must be dealt with in breeding. (a) Clonal varieties, reproduced from buds, cuttings, grafts, or tillers, present the simplest problem. In cases of the species, varieties of which can be thus propagated from single mother plants, the heredity of the entire new variety is determined in the fecundation of the seed of the exceptional parent chosen to become the clonal mother of a new variety. The variety is simply the original seedling plant cut into pieces and each piece grown into a plant, or grafted on another plant. Making the rare plant into a new variety is here a comparatively easy matter. Thus each apple, potato, and strawberry variety springs from a single seed. The apple tree of rare value is divided into cuttings, each of which is grafted

upon a piece of root and becomes a clonal tree, or is grafted on a limb and becomes a clonal part of a tree. The potatoes of the parent seedling plant are mere branches of underground stems, not seeds; and, when planted, each tuber or piece of tuber produces a clonal plant. The runners of the parent seedling strawberry send down roots from their joints, and as the stems which connect the new growth with the old die the new growth becomes a separate clonal plant.

(b) In self-pollinated varieties, where the stigma is fertilized by pollen from the same floret, or at least from the same mother plant, as in barley or wheat, the problem of selection is likewise simple. Here the breeder multiplies the unmixed blood of the rare mother plant found to have exceptional projected breeding efficiency or power to produce its kind along a desired line. There is no danger of outside pollen swamping the new variety, as a new variety may be swamped in open fertilized species of plants, or as a new type of animals is swamped by admixture of its blood with that of the common animals of the breed or species. Thus many new varieties of wheat, barley, and other self-pollinated species have been made, each from a single mother plant. In these varieties the blood of the plant with rare value is sought out by so testing as to compare the average values of the progeny of many, multiplying for general use the blood of any superior mother plant which proves of special value.

(c) Open-pollinated varieties require more care. In this case a variety can not usually be made from a single mother plant; the network of descent in the species is not accustomed to

self-pollination. Only rarely, in many of these species, it is believed, is there a plant with the ability to so endure self-pollination as to make it practical to make a variety from a single mother plant. The seeds of those plants, or open-pollinated species, which show such exceptional individual excellence as to be chosen for mother plants are usually cross-pollinated with many neighboring plants. This makes a trial of the breeding value of plants resulting from these cross-bred seeds, by growing their progeny in comparative tests, only a partial test of the values of the respective mothers, because at least part of the florets were fertilized with pollen from plants other than the mother plant. And while the progeny are growing in centgener tests their flowers in turn are usually cross-pollinated. This often makes it necessary to keep some of the seeds of the original mother plants, so that seeds with as little outside blood as may be are available to use in multiplying the blood of mother plants whose excellent progeny show them to have unusual power to project their values into their progeny. But even when one finds the plant in which rare individual excellence and rare power to project its efficiency into its progeny are combined, its blood can not be multiplied without either often violating its nature by being self-pollinated, or again allowing the plants to be cross-pollinated with pollen from other plants. Breeders are learning how to control the mating so that only good plants of superior breeding, as of corn, which has its male and female flowers on separate parts of the plant, or hemp which has its male and female flowers on separate plants, serve as males to produce the pollen. Abundant proof is at hand that even under the existing difficulties the valuable blood of the individual corn plant with

rare breeding value can be segregated and made into an improved pure-bred variety.

The experiences of more than twenty-two years have centered methods about plans for finding the (1) rare clonal mother, (2) of finding the rare self-pollinated mother; (3) of finding the rare open-pollinated group of parent plants with power to endure rather broad inbreeding, or with the necessary prepotency to overcome blood necessarily injected from other plants; (4) of finding the group of rare open-pollinated mothers whose blood forms a mixture, a network of descent, which when multiplied into a variety is a substantial improvement over the old variety, and (5) of finding the group of rare male and female plants in dioecious species, male and female flowers on separate plants; in either case the plant or limited group of plants with high breeding efficiency whose blood forms an improved variety.

With a view to brevity and clearness the following nomenclature has been used throughout this bulletin:

Foundation stock.- Any subvariety, or variety, or species from which superior plants are chosen as mothers of centgeners, or as the parents to use in hybridizing two stocks.

Hybrid.- The product of the union of varieties or species; the plants of the hybrid group usually varying too greatly to be called a variety, rather to be considered a varying mixture of blood from which new varieties may be selected and segregated.

Hybrid variety.- The restricted group selected out of a hybrid, the somewhat narrowly bred network of descent of which has cultural value.

Mendelian hybrid.- A group of plants in whose network of descent two or more Mendelian characters from different foundation stocks are formally recombined as pure homozygotes.

Selects.- Plants chosen from the foundation subvariety, variety or species because of individual excellence.

Hybrid selects.- Plants selected for their individual excellence from hybrid stocks.

Mendelian selects.- Hybrid plants selected for their individual excellence which in two or more unit characters have pure homozygotes.

Proficients. Plants, the progeny of which in centgener tests have shown them to have high projected efficiency or breeding power.

Hybrid proficients.- Hybrid plants whose progeny have made high projected proficiency records in centgener tests.

Mendelian proficients.- Hybrid plants of the second or later generations in the progeny of which two or more pure Mendelian characters are recombined, and whose centgener efficiency is also especially high.

SOME GENERAL FACTS CONCERNING HEREDITY.

The following statement gives some of the general facts on which are based the discussions in this bulletin.

In each species or variety the sum of inherited characteristics is woven into a nearly stable but most variegated "network of descent", using that term as suggested by Cook.

The individual plants have in their living substance this something known as heredity which, projected forward through the

generative cell from parent to progeny, sometimes in mathematical proportion but with varying impulses, gives character to the individual plants, and endows each with both a different individual value and a different power in its turn to project into its progeny lesser or greater values. A slightly different form is assumed by each individual, that is, heredity expresses itself differently by building a slightly different individual; but the important fact in creative breeding is that there are rare cases in which this difference is marked.

Even more noteworthy is the fact that among these unusual individuals there is an occasional one in which the new form or other character or group of characters mysteriously gains a strong hereditary status and is powerfully projected forward into its progeny, giving this plant or animal unusual potency as a parent of a new variety or breed.

In species propagated by cuttings this heredity is directly multiplied asexually without material variation through sexual reproduction, and without adulteration by sexual admixture with the blood of other plants.

In a self-pollinated species, the progeny of the plant with superior breeding value, if segregated and seminally multiplied, also forms a new strain, a new variety, or even a new species, without sexual adulteration by other blood.

In open-pollinated species an occasional individual superior both in its individuality and in its ability to project its efficiency into its progeny is also prepotent over the blood with which it is in competition when crossed with other individuals, and

Fig. ~~X~~ 1. Wheat Breeding Nursery at the Minnesota Station in 1895.

Fig.~~1~~7. Field Crop Breeding Nursery at Minnesota Experiment Station in 1898. A.- North half. B.- South half.

Fig. 3. Shows the size and scope of a portion of the field crop nursery at Minnesota Experiment Station in 1903. Barley and flax at left, wheat in center, winter wheat and oats at right, bromus, left rear.

Fig. 4. Harvesting Centgener Plats. Nursery notes center around the individual plant and around the centgener plat which is the progeny of a single mother plant. Here a part of the centgener plats have been harvested, the bundles wrapped with cotton to prevent loss from birds, and tied to stakes to hold them erect.

is, therefore, very useful in forming an improved variety.

In an open-fertilized species which will endure self-breeding, the blood of a single plant with powerful heredity can be segregated and thus the newly created characters kept pure.

In an open-fertilized species which will not endure self-breeding the new pattern must indeed be powerfully projected else the old and stable patterns of the species with which its blood mingles in the network of descent will swamp it and not allow it to be segregated as a new strain.

In an open-fertilized species where continuous self-fertilization or very narrow line breeding are not possible, it is necessary to make the useful new variety by securing a blend of the heredity of a group of individuals which breed strongly in a given desired line, and which when bred together form a network of descent which will have high value.

The greatest practical law of creative breeding is: Only one in many, even in thousands of tens of thousands, of a given species or variety is exceptional in its power alone or associated with the blood of other individuals to serve as a progenitor of a valuable new strain.

ORGANIZATION OF PLANT-BREEDING ESTABLISHMENTS.

In the year 1898, when the work herein reported was broadened by bringing into cooperation the experiment stations of North Dakota, South Dakota, Iowa, and Wisconsin under the general cooperative auspices of the Bureau of Plant Industry of the United States Department of Agriculture, Professor W. M. Hays was delegated by the Department to have a general supervision of this cooperative work.

Since 1905 Professor Andrew Boss, assisted by Messrs. Bull, Parker, and others, has had charge at the Minnesota station. Dean J. H. Shepperd, of the North Dakota Station; Professor E. C. Chilcott, Professor E. C. Saunders, Professor W. A. Wheeler of the South Dakota Station; Professor P. G. Holden and Professor L. C. Burnett of the Iowa Station, and Professor W. A. Moore of the Wisconsin Station, were in immediate charge of the cooperative work in their respective States. The expense was shared by the National Department and State stations. The following names field crops were brought under these efforts: Alfalfa, barley, navy beans, soy beans, stock beets, sugar beets, bromus, alsike clover, red clover, white clover, corn, flax, hemp, millet, oats, field peas, cowpeas, rye, sorghum, timothy and wheat; and methods are suggested for breeding a few other plants.

The authors realize clearly that the intricate work of improving our staple crops by breeding can not here be stated in anything but a tentative way. Progress during recent years has been so rapid that improvement may be expected which will radically change many of the plans now in use. On the other hand, many of the suggestions made as to the organization of plant-breeding establishments, the manner of arranging land into fields and plats to be used in plant breeding, methods of numbering varieties and nursery stocks, and methods of distributing improved varieties of plants as here outlined, having for the most part been tried and found practical in actual experience, it is hoped will prove not only suggestive, but in many cases permanently useful. There is great need that those who have ability to devise improved methods of

breeding our great staple crops should contribute to the literature of the theoretical and business sides of this question, that the best plans now in vogue may be widely known and put to the test, that they may be rapidly improved.

PROGRESS IN COOPERATIVE BREEDING OF FIELD CROPS.

The progress of the work carried on by the several cooperating institutions has been very satisfactory. In a number of species effective methods have been devised and important results secured in the form of new varieties. Some of these new varieties, proving to give increased yields per acre, have already been distributed to farmers and now cover millions of acres and are adding annually tens of millions of dollars to the value of the crops of the Middle Northwest. In other species the development of methods has required a longer time and no new varieties have been distributed. In all species, however, work is now in progress under methods which assure improved varieties. The general plan has become more comprehensive from year to year; some new facts and principles have been established; many technical methods have been devised; numerous machines and devices have been invented; and a comprehensive system of pedigree plant breeding records have been developed. Highly efficient plans of rapidly disseminating improved varieties, whether acquired from without the State, or newly bred, are being rapidly evolved. Many facts and methods have accrued which are recognized as widely useful. Most important of all are plans of organizing in each State one or more plant breeding establishments adapted to attacking the problem in an adequate way, warranted by the millions of dollars worth of increased crop products at stake. That results

in hundreds of millions of dollars worth of additional crop yields in the United States can be thus secured with a relatively small expenditure is a demonstrated fact. These investigations have demonstrated the practicability of the Federal and State governments cooperating with individual farmers and associations of growers, and thus, ar comparatively small public expense, directing the breeding along scientific and practical lines. State plant-breeding establishments, in which the work is encouraged and guided in a general way by the United States Department of Agriculture, promise to aid greatly in solving the question of varieties with power to yield more net value per plant and per acre. A public expenditure equal to one-fifth of the added crops would be justifiable. So far the indications are that $1 of public money can thus be made to return $10. to $1,000.; or on an average probably $50. to $100. from each dollar of public expenditure.

NEW VARIETIES PRODUCED.

New varieties of the staple field crops are rapidly coming forward from this work, and from the general work of plant introduction, in which the stations are cooperating with the United States Department of Agriculture.

In connection with the detailed methods of breeding twenty-   crops given in the last part of the bulletin are shown the results of some of the varieties introduced or originated and distributed during the past several years from several experiment stations or from the United States Department of Agriculture. As will be seen, numerous new varieties which are now in the lead in the competition to head the list for distribution have sprung from the nursery breeding. Especial attention is called to numerous selected and hybrid wheats; new oats bred by selection; new flax varieties bred by selections alone; and new selected barleys.

Many newly originated and newly introduced varieties at the respective State experiment stations are under trial, a goodly number of which promise to win the right to be distributed to growers; since under field tests at the stations they have given assurance that they will greatly increase the yields of the farms of the region to which they are adapted. Records of the more pronounced results at the several stations are given in the latter part of this bulletin under the respective field crops. The evidence there is abundant as a basis for the belief that twenty-five percent can be added to the yields in value per acre of our leading crops; and abundant also for the business assurance that ten percent can be added early and at a cost so low as not to form a material item

In view of the fact that this country, and the world, seems to have entered upon a permanent period of high prices for food, plant and animal improvement by breeding becomes one of the world's most vital problems.

These several plant-breeding establishments have also aided in introducing mainly from other countries Manshury barley, its better yielding relative Mandscheuri barley, and Oderbrucker barley, brome grass, Grimm alfalfa, durum wheat, Swedish oats, and numerous other varieties into the agriculture of the Northwest.

The results already secured give a basis for the hope that through plant transfer and breeding thus cooperatively organized all field crops can be made to yield increased values, and that the necessary changes in the breeding power of the crops now in use can be made at a merely nominal cost as compared with the increased values. In the statements made in the latter part of this bulletin regarding the methods of breeding each of the twenty-crops, the attempt is made to illustrate in detail how the facts learned and the methods devised are used in the practical work of improving the species there discussed. A few species not bred by the authors are included to aid in suggesting more broadly to the student and breeder how to devise plans for breeding the many species needing improvement.

LARGE INTERESTS AT STAKE IN BREEDING PLANTS.

That the nearly five billion dollars' worth of plant products annually grown in the United States can be increased ten per cent by breeding is not seriously doubted by those best able to judge. The addition of ten or more billion dollars' worth of pro-

ducts every twenty years by thus readjusting the hereditary tendencies of our crops at a merely nominal cost is as important as the development of electrical methods and appliances, or as the perfection of a system of public highways, or as our entire foreign commerce. If, as is believed, our plant forces can have their heredity so improved that $1. expended in breeding creates $1,000., $100. or even $10., it is certainly a good business proposition rapidly and freely to develop the breeding projects in which public and private agencies must cooperate. The evidence shows that this proposition is opening up in a new form that can not be ignored. Our country is destined to see breeding projects develop, as it has seen mechanical progress grow. Heredity in our plants is as potent an economic factor as are mechanical forces, and is worthy of as serious efforts to develop it.

Table 1 shows the averaged yields per acre in the United States of corn, wheat, oats, barley, rye, flaxseed and potatoes for 1899 to 1903, inclusive, as given by the United States Department of Agriculture. In the right hand column are figures for the crops made higher to show how modest they seem even when ten percent is added to each crop. That these averages can be attained by breeding alone no one acquainted with the results from breeding can doubt.

Table 2 gives the estimated increased returns from breeding the leading field crops and domestic animals in the United States assuming that ten percent can be added; and

Table 3 shows the estimated increased returns in Minnesota.

Table 1. Ten-year averages yields per acre in the United States of seven leading field crops, and yields with ten percent added.

Crops.	Average yield, 1899-1908.	Increased 10 percent.	Crop.	Average yield, 1899-1908.	Increased 10 percent.
	Bushels.	Bushels.		Bushels.	Bushels.
Corn	25.8	28.4	Rye	15.8	17.4
Wheat	13.8	15.2	Flaxseed a	9.5	10.5
Oats	29.4	32.3	Potatoes	89.6	98.6
Barley	25.8	28.4			

a Average for seven years.

TABLE 2.- PROBABLE INCREASED RETURNS FROM BREEDING LEADING FIELD CROPS AND DOMESTIC ANIMALS IN THE UNITED STATES.

Crops.	Value, 1907.	Increase on Account of Improved Breeding.
Corn	$1,336,901,000	$133,690,100
Wheat	554,437,000	
Oats	334,568,000	
Barley	102,290,000	
Rye	23,068,000	
Buckwheat	9,975,000	
Potatoes	184,184,000	
Hay	743,507,000	
Cotton	700,856,000	
Tobacco	76,234,000	
Flaxseed	24,713,000	
Total (of above crops)	4,090,833,000	$409,083,000
All other crops a	622,798,610	62,279,861
Total (all crops) a	4,713,631,610	471,363,161
Value of products from live stock	2,101,665,914	210,166,591
Total value of crops and products from live stock a	6,815,297,524	
Estimated increase on account of breeding improved plants and animals a.		681,529,752
Population (1906) a	83,941,510	
Increase per capita a		$8.12
Number of farms (census)	5,737,372	
Increase per farm a		$118.79

a Estimated.

TABLE 3. PROBABLE RETURNS FROM BREEDING LEADING FIELD CROPS AND DOMESTIC ANIMALS IN MINNESOTA.

Crops	Value, 1907.	Increase on Account of Improved Breeding.
Corn.	$21,802,000	$2,180,200
Wheat.	62,192,000	
Oats	25,414,000	
Barley.	17,864,000	
Rye.	1,079,000	
Buckwheat.	54,000	
Potatoes.	6,004,000	
Hay.	11,475,000	
Cotton.	....	
Tobacco.	....	
Flaxseed.	4,878,000	
Total of above crops	150,762,000	15,076,200
All other crops a	5,234,865	523,487
Total all crops a	155,996,865	15,599,687
Value of products from live stock a	64,222,237	6,422,228
Total value of crops and products from live stock a	220,219,102	
Estimated increase on account of improved breeding a		22,021,915
Population (1906) a	2,025,615	
Increase per capita a		$10.87
Number of farms (census)	154,659	
Increase per farm a		$142.39

a Estimated.

POWER OF HEREDITY IN THE SEED.

The power of heredity may be illustrated by using known facts in wheat breeding. The two varieties of wheat, Minnesota No. 163 and Minnesota No. 169, mentioned under Breeding Wheat, p. , each originated from a single mother plant in 1892; Minn.163 from a seed of the variety known as Fife, and Minn.169 from a seed of the variety known as Blue Stem, both grown in 1891. During twenty years the two varieties springing from these two seeds have multiplied by self-pollination. No blood from outside plants has been mixed into their heredity and these varieties it is believed are now sown in millions of acres. It is believed further that the parent Fife and Blue Stem varieties originated from single mother plants and that for several decades there has been so little cross-pollinating in these great wheats of the middle Northwest as to make that a negligible quantity in the general value of these wheats, though sufficient to produce some intercrossed stocks within the variety.

Given two ordinary mixed stocks of wheat which, under given conditions, yield 20 bushels per acre, it is possible to find individual plants in each of these two varieties, which, if their seeds be multiplied into strains, will yield the same as their parents 20 bushels per acre. Again, other plants may be found in each which, if multiplied, will yield twenty-five instead of twenty bushels per acre.

If the parent seed is so planted as to give the chosen plant ample space it will produce more than 1,000 seeds. If, in their turn, each of these 1,000 seeds be planted with a similar

amount of space, 1,000 seeds from each can be produced the second year, 1,000 from each of these the third year, and so on. If it were possible thus to provide the full quota of room for each plant, in nine years sufficient seeds could thus be produced from a single original seed to sow an area as large as the surface of the entire earth. And for the sake of the illustration the ability of each seed of each successive generation to produce 1,000 seeds when given abundant room and all other favoring conditions must, of course, be granted. Each of the seeds thus produced, so far as heredity is concerned, could be used to again produce in the next ten years another world area of wheat, and so far as heredity is concerned this could be continued yet a third and a fourth ten years.

The difference in amount of wheat of a variety from a mother plant with breeding efficiency to produce twenty bushels per acre and a variety from a mother plant with efficiency to produce a twenty-five bushel per acre wheat would be practically infinite in quantity. Yet again, if the difference in these yields be in part because the two varieties die out in winter, and by crossing two varieties, or even by making intra crosses among the plants of the variety an occasional hybrid plant can be secured which will produce a variety which, being hardy, will yield thirty bushels, the seeds from a plant of this hardy stock could in like manner be increased to a quantity quite beyond comprehension. Thus one would have a variety producing in quantity infinitely greater than that produced by the variety yielding twenty-five bushels per acre - and, by crossing, this infinitely larger amount would be created by the breeder. That the projection of improved yields and values through heredity is one of the world's great economic forces needs no clearer demonstration.

The seat of special breeding efficiency, in case of any character or group of characters, is in the seed and is there installed at the time the parent male and female germs are united in forming the seed. Whether in clonal varieties, as apples or potatoes; in seminal self-pollinated varieties, as in wheat and barley; and in seminal cross-pollinated varieties, as in corn and rye, the breeding efficiency has its basis in the heredity fixed at the time of impregnation of the ovary. Illustrations of this are apparent in the Wealthy apple, a clonal variety from a single seed; in Minnesota No. 169 wheat, a self-pollinated variety; and in Funk's No.120 corn (Number afterwards changed to 120 oil), an open-pollinated variety, strong both in economic efficiency and apparently strong in ability to endure self-breeding. Among animals we find similar incidents, where an occasional animal begets progeny which is the basis of a family or breed, and in some cases will endure inbreeding; and more families and breeds of animals as well as varieties of plants are found to thrive under narrow breeding than was formerly believed. That environment as compared with the organization of the inherited forces is relatively a much smaller factor in determining the power with which a character is transmitted to future generations, has come to be a clearly recognized fact by the best informed breeders.

Of all factors relative to the improvement of plants, the common knowledge that there is one individual in a thousand, or in many thousands, which has great breeding efficiency, is manifestly of transcendant practical importance. It may be called the first great law of creative breeding. And the fact, that by hybridizing individual plants of even higher breeding efficiency, though more

rarely occurring can be created, is entitled to a place beside the first law. The great practical fact is that these rare plants can be sought out by testing the average values of the progeny of each, the blood of these mutating parents segregated; and that from these individuals superlative in their projected breeding efficiency, or from interbreeding groups of such individuals, valuable new varieties can be produced. There is need both of keeping up and improving the breeding value of standard varieties, and also of creating new and still better varieties. Creative breeding is only in its infancy, and there is need of much research into the arts of keeping up and improving the values of standard varieties.

STATE PLANT-BREEDING ESTABLISHMENTS.

The methods of breeding outlined in the following pages are not offered as matured work. They are given as a report of progress, and in some cases as suggestions, based upon much work, with the hope that they may serve in some measure to aid those who are entering upon the business of breeding plants and animals, or of research into the problems of heredity and breeding.

An effort is made to illustrate how a large plant-breeding establishment may be organized, and especially how State experiment stations with branch stations and with State and Federal support can organize the work of improving the crops of the State. The effort is made, however, so to carry out this illustration that the methods will be suggestive to the private breeder or to other public agencies engaged in breeding plants.

Carrying the work to its logical economic conclusion in Minnesota and other States by actually making general introduction

Draughtsman: Use same cut as
Fig.4, p.22, O.E.S.Circular 84.

Fig. 5. Map showing State Experiment Station, and suggested locations for three or four hundred branch experiment stations.

of newly created improved varieties of field crops has forced the conclusion that efficient plans for distributing accredited new strains are quite as important as the methods of creating strains of plants with increased values. A separate chapter is therefore devoted to the subject of distribution of seeds and plants to growers; giving actual experiences with the general business methods of commercial distribution successfully employed by the Minnesota and other experiment stations in cooperation with the United States Department of Agriculture.

The organization of State plant-breeding establishments is not altogether new and untried, and some statements of experience may properly be made. The Minnesota station has the oldest of such well-developed establishments in the United States. Its present cost to the Minnesota Experiment Station and the United States Department of Agriculture is less than twenty thousand dollars annually. Nearly a dozen varieties of corn, wheat, barley, oats, and flax, supplied to the Minnesota farmers as a result of this work, are believed to add annually upwards of two million dollars to the value of Minnesota crops above what would otherwise have been produced by the common varieties which these new strains have displaced.

It is therefore a conservative claim that theMinnesota State establishment for breeding field crops produces for the people of the State more than a hundred dollars for each dollar expended, or a net profit of one million, hine hundred and eighty thousand dollars annually. Since this work is only begun, it is believed that it is impossible to easily increase this profit to $10,000,000. or even above $20,000,000. annually. To secure this result there

Fig.6. Map of Minnesota showing the location of the State Experiment Station; the State College of Agriculture, the St. Anthony Park Agricultural High School, and other schools relating to agriculture being also located on University Farm, with the main campus of the University of Minnesota three miles distant at 4; the Crookston Branch Experiment Station and the Crookston State Agricultural High School at 9; the Grand Rapids Branch Experiment Station at 8; the recently chosen location for the Morris Agricultural High School and Branch Experiment Station near 5; and a very roughly outlined plan suggesting locations for six other branch station farms and agricultural high schools in the regions of 1, 2, 3, 6, 7 and 10. The relative sizes of all the larger towns and the cities of the State, as given by the Census of 1900, are shown by black circles, showing approximately their relative population.

must be some liberality in supplying the necessary funds for the organization and maintenance of plant-breeding establishments, that work with all crops may be vigorously prosecuted. That the cost will not be great for an establishment adequate to the task of making from all our semi-civilized plants important pedigreed varieties, and for making useful varieties out of many wild species, is amply proven.

As shown on a previous page, there are produced in the United States plant and animal products worth several million dollars which can be improved by breeding. Assuming that at small cost ten percent can be added to this value the average profit per farm will be over $100., and the average profit per capita to the entire population would be over $8. The organization and installation of State plant-breeding establishments is exceedingly important, and the work, equipment, and management should serve as an example for private persons who may desire to enter upon similar enterprises.

Men with a genius for this work, which is at once a science and an art, should be sought out, educated, and given adequate salaries, assurance of civil-service tenure of office, and the necessary facilities with which in a large way to undertake the breeding of all important plants and animals.

In addition to expert leaders and experienced workmen, lands, buildings, teams, and mechanical equipment are necessary for plant breeding. On experiment farms it is very important that a foreman of plant-breeding work and one or more permanent hands be employed. The salaries and tenure of office of these men also should

be such as to insure permanency of workers. This obviates the embarrassment and difficulty of initiating new help into the work and maintains continuity and therefore greater efficiency of the work. The work should be systematically developed so that it can be continued from year to year and can be increased in volume as experience warrants. Since one of the basic principles is that plants with exceptional breeding power occur only rarely, it is necessary to have facilities making it possible to use very large numbers.

BRANCH EXPERIMENT STATIONS NECESSARY.

Numerous States have come to realize that experiment farms or fields on each of its general soil areas, or rather in each of its general agricultural regions, are a necessity to aid in developing varieties of plants and systems of farm management for all parts of the State. In plant breeding, these farms , if properly selected, will enable plant breeders to test imported, newly introduced, and newly bred varieties so as to determine those peculiarly fitted to produce larger values under the various conditions of the State, and to breed varieties suited to local conditions. The physical, chemical, and biological character of the soil, both for the nursery work and for the variety test plats, should be as nearly as possible an average representative of the soils and farms of the agricultural region for which the improved varieties are designed and should be kept in somewhat better condition than the average of the practical farms of the region served.

The map in Fig. showing the Minnesota State Experiment Station and suggested locations for branch experiment stations, illustrates a plan for a comprehensive State organization entering

upon the breeding, testing and introducing of new varieties of useful plants.

The selection of lands for an experiment station farm is of first importance. Large areas are necessary of nearly level land which lends itself readily to suitable subdivision into nursery and field test plats uniform in character, the soil of which is typical of the region for which plants are to be bred.

Fig 7.

Should be a map here showing subdivision of a county. Possibly we can use Olmsted County.

The map in Fig.   shows how counties are being redistricted so as to consolidate the little one-room rural schools to and from which the farm youth walk, into districts covering areas five or six miles square, with four or five-room schools to and from which the pupils are drawn in school wagons. Twenty consolidated and village rural schools, each with a ten-acre farm, will provide two hundred acres of land per county. Fifty or more acres of this can be used for testing varieties of plants. If each county in a State with one hundred counties would thus devote fifty acres to testing varieties of crops, or five thousand acres in the entire State, the teachers of these schools, the pupils and the farmers generally would know very much better than now what varieties of field crops, orchard and fruit trees, also of garden vegetables and small fruits to plant. Besides, they would have before them examples of high yields and of excellence in their own neighborhoods and under constant comparison with the yields on their own farms.

Hand sized plats for testing varieties of field crops can be successfully handled by the teacher and pupils, as can also small plats of vegetables and small fruits; and the species and varieties of forest, ornamental and fruit trees can be tested with a few specimens of each kind. The county superintendent of schools can cooperate with the State Experiment stations in securing the averaged results of the trials of the varieties of a given crop or tree at all the consolidated rural school farms of the county and of other farms where tests are made.

A State with one hundred counties might properly devote two hundred acres of the State experiment station farm to breeding

plants; fifty acres on each of ten branch station farms, or five hundred in all; and two and a half acres on each of two thousand consolidated rural school farms, or five thousand in all. The farmers of the State now spend many times that acreage in trying in a most inefficient way new field crops, fruit trees, small fruits and vegetables. The expense to the State would not be one-fifth what these desultory experiments now cost, and since they would be done as a part of the educational machinery of the State the cost would hardly be noticed. But the main reason for this expenditure would be that the crops of the State may be increased by fifteen to twenty-five millions of dollars annually. The main reason for connecting the breeding work with the institutions devoted to education for farm youth is that by this means the farmers will be led to keep in vital touch with the variety testing and will at once adopt all things really proven more valuable than varieties already grown. Nearly as important is the educational value to the students of this breeding, variety testing and the distribution of valuable new varieties. The teachers in schools devoted to education for country life are given a more vital status if they have also duties and opportunities in research and in improving the plants and animals of their patrons.

LAYING OUT EXPERIMENT FARM FIELDS.

In laying out a new experiment farm, certain general principles should be followed. It is necessary to systematically divide the experiment farm into fields with lanes and roadways easily connecting the respective parts with the buildings and barnyards.

A convenient system for designating the fields is neces-

sary. The use of capital letters has been found satisfactory, as Field A, Field B, etc., though short proper names may occasionally be preferable, as Hill Field, Jones Field, etc. On large experiment farms where the letters are all in use additional fields may be given proper names.

DIVIDE FIELDS INTO SERIES FOR CROSS PLANTING.

It is convenient to divide these fields into series, or small fields of uniform width, as long as the width or length of the field, or as long as chosen uniform areas will allow, and to surround them by alleys twelve to sixteen feet wide for turn rows. The plats across the series may be made any needed width for seeding lengthwise of the plat, thus securing plats of any desired uniform size.

METRIC SYSTEM IS CONVENIENT.

It is well to lay out these fields under the metric system, as this is a much more convenient system to use in all calculations, and may at some time become the legal method used in the measurement of area. A convenient width for the series is 40 meters[a], practically 8 rods, or in some cases 80 meters. Where series 8 and 16 rods wide have been established they can be made 40 and 80 meters wide by adding 1 or 2 feet to the width of the alleys, thus slightly reducing the width of the plot to make it fit the metric system of units. Plats running across these series can then be used 5, 10, or 20 meters wide, making series containing 200, 400, or 800 square meters on the series 40 meters wide. Two hundred square meters is one-fiftieth of a hectare and 400 square meters is one-twenty-fifth of a hectare.

a A meter is 3.28 feet; 40 meters are 131.23 feet; while 8 rods are 132 feet.

Fig 8 Make another drawing showing formal scheme for crop rotations and metric system.

Fig.9. Method of laying out plots for nursery centgener plots. A portion of a series of land showing; I a method of planting the nursery when the soil is uniform, and II a method of planting the nursery when the soil is not uniform.

I. Centgener beds 1, 2, 3, etc. are planted the full width of the series, except the border space, which is always left as a means of securing uniformity for all centgener plots.

II. Blocks A, B, C, D and E are made any convenient size to fit the soil conditions of the series, and are usually separated by a 4 foot alley at the ends of the centgener beds. The centgener beds, here 1-8 inclusive, are planted two feet apart. The areas between blocks D and E being low is planted to increase or bulk grain.

FIG. 10 - A *ROTATION SCHEME MINNESOTA UNIVERSITY FARM.

1907. Sp. Nursery (10 T. Manure)	1907. Sugar Beet Nursery	1907. Nursery - W. Wheat	1907. Peas - Winter Wheat Nursery	1907. Corn Nursery	1907. Rye - Clover	1907. Peas - W. Rye
1908. Peas - W. Rye	1908. Sp. Nursery (10 T. Manure)	1908. Sugar Beet Nursery	1908. Nursery - W. Wheat	1908. Peas - Winter Wheat Nursery	1908. Corn Nursery	1908. Rye - Clover
1909. Rye - Clover	1909. Peas - W. Rye	1909. Sp. Nursery (10 T. Manure)	1909. Sugar Beet Nursery	1909 Nursery - W. Wheat	1909. Peas - Winter Wheat Nursery	1909. Corn Nursery
1910. Corn Nursery	1910. Rye - Clover	1910. Peas - W. Rye	1910. Sp. Nursery (10 T. Manure)	1910. Sugar Beet Nursery	1910. Nursery - W. Wheat	1910. Peas - Winter Wheat Nursery
1911. Peas - Winter Wheat Nursery	1911. Corn Nursery	1911. Rye - Clover	1911. Peas - W. Rye	1911. Sp. Nursery (10 T. Manure)	1911. Sugar Beet Nursery	1911. Nursery - W. Wheat
1912. Nursery - W. Wheat	1912. Peas - Winter Wheat Nursery	1912. Corn Nursery	1912. Rye - Clover	1912. Peas - W. Rye	1912. Sp. Nursery (10 T. Manure)	1912. Sugar Beet Nursery
1913. Sugar Beet Nursery	1913. Nursery - W. Wheat	1913. Peas - Winter Wheat Nursery	1913. Corn Nursery	1913. Rye - Clover	1913. Peas - W. Rye	1913. Sp. Nursery (10 T. Manure)
G	F	E	D	C	B	A

*Repeat next 7 years - 1914 to 1921.

Pay ~~117 $\frac{1}{2}$~~ 71$\frac{1}{2}$

On series 3 rods wide, plats 8 rods long and 1 rod wide are one-twentieth acre, and plats 2 rods wide are one-tenth of an acre. Since the metric hectare is 2.471 acres, these plats compare with the one-twentieth and one-tenth acre plat now commonly in use in variety tests, as follows: 200 square meters (one-fiftieth hectare), equals 0.0494 acre, lacking only 0.0016 of being one-twentieth of an acre, and 400 square meters is one-twenty-fifth of a hectate and is practically one-tenth of an acre. These dimensions are as convenient as the rod and acre.

Since the acre and other nonmetric units are in common use, facts recorded under the metric system are translated before publishing, using metric expressions only occasionally as an aid in educating the people in the use of the metric system. In very many cases such statements as the footings of tables and general conclusions given in figures should be stated both in metric language and in the language of the country. Thus, additional columns in summary tables in which general facts are stated in metric units besides those given in the common units help to bring about uniformity. If all countries would thus give general facts in additional metric statements much time would be saved, and the language of science would become easier and more nearly universal.

SERIES MAY BE RECTANGLES OR SQUARES.

In some cases these series may be laid out in square blocks and the plats placed across them east and west the first and third years, and north and south the alternate years. Thus a square series may be planted to plats of sugar-beet varieties running east and west in 1912, and then wheat varieties may be sown in plats running north and south in 1913.

When the series are relatively even in their producing capacity, or have been cropped rather uniformly, they need no particular consideration other than the alternation of direction in planting. But where the crops on the respective plats differ materially in their effect on the fertility of the soil, the intervening crops should be planted uniformly over the series, that the soil may be given time again to reach approximately its previous uniformity. And, if

LAYING OUT PLOTS FOR CENTGENER TESTS.

In Figure 9 a portion of a series as in Figure 8, showing how to lay out the plots for the centgeners when the whole is not sufficiently uniform to permit of its use entire for breeding purposes. The blocks "A" may be used any length permitted by soil conditions. In case of uneven land the width of the series will also depend on soil conditions, likewise the width of the centgener plots used. The centgener frames "B" for hill plats of small grains are usually five feet wide and so constructed that the centgener plats may be arranged in series of rows of the desired length. The usual 16-foot wide roads bound the Series, broad 5-foot alleys bound the blocks, and 2-foot wide alleys separate the centgener beds from each other. When the soil of the series is uniform throughout the centgener beds may be run the entire width of the series (1320) feet. In this case these beds are 5 by 132 feet in size, as in I, Figure 9.

NURSERY CROP ROTATION SCHEME NECESSARY.

In Table 4 is shown a statement of a rotation scheme adopted in 1907 on seven series of about two acres each, or 8 x 40 rods, on Minnesota University Farm. For each year from 1907 to 1913 this rotation plan provides land prepared by the previous cropping for a nursery area for each of several crops. This seven-year rotation scheme can be projected forward indefinitely by beginning in 1914 with the same crops as were planted in 1907, and in the succeeding years, repeating the entire seven-year course of cropping.

Fig.11. Showing series in rotation scheme.

Note:- Directions for Carrying out the Rotation Scheme.

1. Peas (winter rye): Plant peas, cut for hay or seed. Plow and sow fall rye (Minn.No.2).

2. Rye (clover): Sow medium red clover in rye, early in spring cut rye for seed. Plow under the clover in September for green manure.

3. Nursery corn: Plant Minnesota No.13 corn nursery and fill out the series with best bulk seed of same variety.

4. Peas (winter nursery): Plant peas early and cut for hay or seed, or if the land needs it plow under green. Plow immediately and plant the winter wheat nursery.

5. Nursery (winter grains): Harvest winter wheat nursery. Plow at once and sow winter rye.

6. Sugar beet nursery: Plow under the rye in spring for green manure and sow centgener rows of beets. Plow late in the fall.

7. Nursery (spring grains) (5 to 10 tons manure per acre): Plant nursery of spring grains. Apply, if the land needs it 5 to 10 tons of manure; using the greatest care to mix to uniform quality and to spread evenly. Spread half lengthwise the series and half cross-wise. Plow deep immediately after harvest.

This rotation is self-explanatory. By reading from the top downward, one will see the succession of crops on each series. By reading from left to right, the crop for any given year upon any given field may be ascertained.

Professor C. A. Zavitz at Ontario Agricultural College has long used four fields in a four-year rotation as follows: First year, grain; second year, grass; third year, grain; fourth year, cultivated crops. This precedes each grain crop with a crop of grass or a cultivated crop, and with that soil and under the climatic conditions there existing, the soil is in good condition for each crop. He can thus use nearly all the land each year for variety test plats, nursery plats and for plats devoted to testing methods of selecting

and cultivating the different species. These fields are divided into series 100 chains wide.

In many cases a fallow crop is grown just previous to planting the breeding nursery plats, primarily to have uniform and favorable conditions. In dry regions bare fallowing may be sometimes necessary to store up moisture and to secure the germination of seeds of previous crops of the same species of plants so as to avoid voluntary plants from seeds which did not germinate the previous year. The use of barnyard manure, or planting on upturned grass sod, sometimes causes trouble from the white grub or other insects which kill so many of the plants in the nursery plat as to make the comparisons between stocks unreliable. On any given farm long years of experience aid the manager of breeding plats to so rotate and cultivate crops on the field used for nursery and field plats in always securing good and uniform stands of individual plants of nursery plats and of field test plats.

Fields, series, and sometimes plats on experiment farms should be carefully surveyed, right-angle or other corners established, and the corners permanently marked. A good mark for the corners of series and permanent plats is a piece of 1-1/2 or 2 inch gas pipe 2 feet long, a stone, or even a piece of hard wood, set at the corner inside the road or alleyway, with its top placed a foot below the surface so as not to be distrubed by the plow. A temporary wooden stake 2 or more inches in diameter placed over the buried pipe, stake, or stone makes a visible mark and when necessary may be easily removed and accurately placed above the permanent buried monument.

Experiment farms to be used as branch stations, such as may be organized in conjunction with agricultural high schools, are not only necessary, that the varieties proving best at the central station and in near-by States may be tested, and that part of the creative work in plant breeding may there be carried out for the respective agricultural areas of the State, but they are also very useful educational adjuncts to the agricultural high schools with which they may be connected.

All tests can not be made on formal plats, laid out in rectangular form on uniform land, giving opportunity to construct formal tables showing average yields, as well as hardiness, etc. In many cases land uneven in texture, elevation, etc, must be used and rectangular plats can not always be secured. In case of many plants, as fruit trees, the individual plants must be the unit from which to judge yield, hardiness, quality, etc. In other cases row tests must be depended upon, sometimes curved rows of uneven length, as in the cotton and corn fields of the terraced lands of some Southern sections. Every species and the place available for breeding it is a separate problem, but where practicable, as in case of field crops, the formal breeding nursery plat and the long field plats whether rectangular in form or a mere row, with soil comparable each with the other, are of great service.

Special Buildings and Machinery Required.

As the large establishment for breeding of field crops develops, as at a State experiment station farm, buildings are needed for threshing and for storing seeds, roots and plants and for laboratory work; and in many instances greenhouses are needed. The laboratory needs are determined by the specific crops and these are shown in some detail further on in the chapters treating of breeding the respective species. Since the work of distribution to growers of pure bred seeds and plants must be done in semi-commercial quantities ample storage buildings with machinery for cleaning, grading, treating for diseases and otherwise caring for commercial seeds are a necessity.

Field machinery is also a necessity, and in many cases special machines designed for preparing the land, planting, thrashing, harvesting, cleaning, grading and testing are required, some of which have already been invented and others are yet to be devised. (See Figs. 18 and 19).

A number of stations have constructed seed houses and seed laboratories. The special barn for threshing and storing seeds at the Ontario Agricultural College has many most admirable features which should be studied by those who need facilities for handling field crops in a large breeding establishment. In the basement are arrangements for storing potatoes, mangels, turnips, and other roots, mainly in boxes. On the first and second floors are bins for storing seeds, and one room for bags and small samples of seeds is so constructed as to be mouse proof and to be fumigated when weevil or other insects require. But the unique and most im-

portant feature is the arrangement for threshing and cleaning the seeds from plats of cereals and grasses. The bundles from each plat are drawn from the field in a flaring tin-lined box on a one horse wagon with compartments for the bundles of grain from two plats which are pitched to the weighing floor which is a story above the threshing floor. The weigher receives the bunch of bundles, places it on the platform of the scales which covers the framework of the scales so that there is no friction to wrongly influence the weights. The bundles are then shoved across into a hopper from which they pass directly into the cylinder of the threshing machine. The threshing machine is a small commercial machine somewhat built over inside so that all surfaces are slanting and no seeds remain in the machine from one plat to be mixed with the seeds of the next plat. One panel is removed from beneath the cylinder to complete the cleaning out of all seeds remaining in the threshing machine. The machine is fastened to the floor of the threshing barn and a straw carrier deposits the straw where it can easily be hauled away. The capacity of the machine is about thirty-five plats per day, and if the man who draws in the grain gets ahead of the machine the plats of grain are stored on two floors built only about seven feet apart. Thus the grain of each plat is placed under cover as soon as ripe and the threshing can proceed on wet as well as on dry days. On the same floor as the threshing machine are fanning mills and machines for grading the seeds. Prof. C. A. Zavitz, who is in charge of this work, uses plats one-hundredth part of an acre and less in area, often down to one four-hundredth or even smaller. He is thus able to use hand methods in the field

work almost wholly after the first preparation of the soil with teams. By carefully trimming each plat to line, and with the greater refinements of work where everything is done by hand, his results are most satisfactory; and his work certainly has some advantages over the larger plats seeded and harvested by team. These small plats also lend themselves to careful work in hauling to the threshing barn, and weighing without the errors incident to weighing the wagon. There is a great advantage in being able to store these smaller amounts of unthreshed grain, which can not so well be done with the one-twentieth and one-tenth acre plats. Then, too, the small plats make it possible often to use the seeds from the centgener plats for variety field test plats without losing a year in growing them in nursery increase plats. The hauling of the bundles of these small plats is done in a wagon box built flaring, with a transverse partition, the front and back compartment each lined with tin so that no seed may be lost. One man with one horse does the hauling from the many hundreds of plats, which are all within half a mile of the barn.

For conditions where the plats are farther from the threshing barn, a large wagon rack could be used, and each small plat could be tied up in a canvas in the field and thus hauled to the barn and stored till the threshers are ready to have it pass over the scales into the thrashing machine. Separate thrashing machines may be especially devised to thrash the small cereals, clover, the finer grass seeds, peas and beans, etc; and each could be on wheels so that it may be quickly placed under the hopper from the scale platform when a particular kind of grain is to be thrashed. The

Fig.12.

Fig.13.

same electric motor could be so attached to each as to give it the proper speed. And the framework of each machine with its movable platform could be so arranged that no seeds would escape to the floor of the room, or provision could be made for sweeping the floor after threshing each plat.

HEREDITY AND BREEDING.

Research in heredity, in natural evolution, and in practical breeding has recently received a mighty impulse from the work of Mendel, DeVries and other investigators, and from the economic and artistic results in practical plant and animal improvement by successful breeders. Darwin's contention that nature evolves her living forms having been generally accepted, the world has become ready to consider as a serious business proposition the employing of science in the problem of making all useful plants and animals to evolve rapidly.

As the more abstract researches in chemistry and physics help to give a basis for advancement in practical mining, manufacturing, and transportation, so practical breeding must rest in part on formal researches in heredity and evolution.

To study the laws governing living things whose essential characters are the sum of millions of years of environmental experiences and impulses wrought into affinities and habits is a most complicated, though most interesting, undertaking. It is not strange that this line of research has not been developed along many clearly defined lines, such as is the work blocked out by Mendel.

The Linnaeus school of scientists magnified the species;

practical breeders have been prone to magnify the superlatively fine appearing individual plant or animal; Mendel magnified the unit characters and the persistence of its unity as it passes through successive generative cells. scientific breeders have come to seek that flux of blood, that network of descent, whether of one or of a group of parent plants, or of animals, which when multiplied will be an improved variety or breed.

There are needed investigations to guide the scientific breeder, whether he be a private individual, the advisor of an association of breeders, the official in charge of a public breeding establishment, or the expert chosen to superintend a large enterprise in which public and private funds are used to produce improved plants or animals for general and wide use. These researches need to cover Mendelism, mutation, and other laws of heredity. The floral habits of all economic plants should be most carefully studied and recorded. Methods of hybridizing many kinds of plants should be devised; and the facts as to which pairs of species of plants and animals may or may not be hybridized should be determined by experimentation. The allelomorphic character pairs should also be widely studied and their segregation and recombination studied and made of record so as to be useful to those studying the theory of heredity, and to those who use these characters as the units in their recombination if indeed not creative work of constructive breeding.

Methods of selecting to improve each species of plants and animals, so as to aid in producing the many needed forms for varied conditions of production and use, should be much more highly developed. In plant breeding there are needed efficient methods

for nursery, field and laboratory tests, and for tests after new varieties are in the hands of growers.

New methods of distribution need investigation, that valuable new forms may rapidly be disseminated, not alone to the few who are the most enterprising, but to all growers who would profit by them. But it is most important of all that the laws which heredity obeys should be wrought out by every known means.

The breeder, the breeding establishment, or the investigator into the laws of heredity should adopt systems of planting, nomenclature, and note taking which are comprehensive yet simple; inclusive, yet thoroughly practical for minor lines of records of breeding or research as well as for the more ambitious and the more complicated enterprises. And where practicable records should be comparable among themselves, but the notes should not take the place of the man. They should help, and not enslave him in details. There is a happy medium between the man who works only on innumerable details and their arrangement and classification, on the one hand; and, on the other hand, the man who makes only brilliant generalizations from material gathered by broad general observation. The ability to broadly correlate, generalize, suggest possible hypotheses, to give strict analytical tests to every theory, and broadly to construct and give intelligibility to a true philosophy needs to be combined with the ability to plan for, organize for, and to conduct the work of vast numbers of detailed operations and of making records of their results. Relatively few men combine the talents of Darwin and Mendel. Most men need other workers to supplement their own talents and efforts. And now that the day of co-

operative organized effort has come in all lines, team work is not only possible but absolutely essential, both in the theoretical study of the laws underlying the art of breeding and in the business of creating new varieties and breeds. Such organizations are needed in experimental genetics as might have been conducted by the joint talents of Darwin and Mendel with a group of assistants highly trained in conducting investigations in heredity, natural evolution, and artificial evolution. And, likewise, organizations, including men of varied talents, are necessary to introduce, improve by selective breeding and by hybridizing followed by selection, and to distribute the improved resulting forms. It would seem that these two classes of workers should be organized much more rapidly than is at present taking place.

It must not be assumed, however, that the scientific investigations or the practical breeding are all to be carried forward by large and complex organizations. Much of the very best work of both classes is being done and will continue to be done by men working singly or in very small groups. Some of the constructive philosophical thought will best be done by men who are not hindered by too close contact with the details of scientific research. And much of the most brilliant results in breeding will continue to come from men like Luther Burbank who work alone.

As the laws of breeding are made available, as systems, methods, devices and machinery are devised, and as means are made available for the research and breeding more of organization will be possible and profitable, both to those engaged in the work and to those who use the resulting plants and animals. It is of great

interest to note that the organization of plant breeding, having but recently overtaken the organization of the breeding of animals from which plant breeders received many of their best methods, is now helping to arouse a new impulse to place animal breeding on a basis for more rapidly improving our domestic animals. Individual breeders of animals have long respected the rule of "breed many and retain only the few best". Plant breeders have proven that this rule must be restated so as to read: Breed many thousands and retain only the very few with highest breeding efficiency".

USEFUL SYSTEMS OF NURSERY NOTES IN THEORETICAL EXPERIMENTS.

Investigators who carry on researches in plant breeding greatly need a system of recording the lineage and the individual performance record, also the breeding power as shown in the progeny of many plants. The system of numbering nursery stocks and individual plants described in this bulletin, having been developed to meet the conditions annually arising in the work of breeding by selection, by hybridizing by selection, and of theoretical experiments with about twenty species representing nearly as many genera will be found to be quite general in its adaptability to keeping notes in breeding plants. It also has features which are of use in practical animal improvement and in theoretical experiments, and even in lineage and performance records in man. It is hoped that this system will be suggestive to those who may devise a better plan of recording the lineage and the individual values and the breeding powers of animals. It was early demonstrated most forcibly that each experiment relating to theoretical questions should be separate from the work of producing improved varieties; and that in

almost all cases each line of investigation should be based on plants used only for the purposes of that investigation. Trying to do two theoretical genetic experiments at once, or with the same set of plants or animals, soon becomes confusing and the results are liable to be made unreliable for the purposes of one of the lines of inquiry if not for both.

GIVE EACH THEORETICAL EXPERIMENT A NUMBER.

It has been found convenient to give each theoretical genetic experiment an experiment number and the general scheme of naming, numbering, tracing blood lines, and recording outlined in this bulletin serves as a good basis for arranging the plan of notes in each of many theoretical experiments. The "Project Statement Scheme" in general used in the U. S. Department of Agriculture and in many State experiment stations was originated in these investigations and the forms followed are especially adapted to this class of projects. The interrelations of many factors made it imperative to have a system of bookkeeping, and necessity became the mother of the project statement scheme.

As elsewhere stated it was found convenient to designate in the Minnesota Experiment Station Field Crop Nursery all nursery stocks under improvement merely by selection by the Roman figure I; stocks under improvement by hybridizing and selection by II; and stocks in use in theoretical investigations by IV. Thus: the experiment named "Seeds compared from heavy vs. light yielding spikes" is given the experiment Number IV 2; and Wheat IV-10, designated "Breeding wheat on good soil vs. on poor soil", for farmers having rich soil and

for farmers having sandy soil. Nursery stock numbers of different stocks used in each experiment may be written thus: IV-10-'06, the right hand preceded by '06 designating a given stock of seeds planted in 1906; IV-10-'06-2; IV-10-'06-3; etc., thus giving both a number-name to the lot of seeds used and the year in which a given lot of plants or their resulting seeds were planted.

In many of these cases great advantage thus comes in the use of a system of numbers which provides a separate serial number to every individual plant in any plot when needed. If, for example, the twenty nursery stocks of 100 plants each in the experiment IV-10-'06 are planted in the nursery, the nursery plant numbers may be taken up where the previous class left off. If the hybrids, Class II, Wheat, for example, closed with plants 87400, the first twenty centgener plats of plants in class IV-10-'06, if planted in the next plat, might begin at 87401, and the last centgener plat, if there were 100 plants in each of the twenty plats would be 89400. In this particular experiment IV-10-'06 the work was carried out on each of two classes of soils as ordinary selection is carried out under Class I, (See page) ~~the first year~~, and the notes of the individual mother plants the first year, the centgener tests of each of twenty nursery stocks in the second, third and fourth years are carried out in the same manner.

Incidentally in devising a method of planting this IV-10 experiment, a plan of planting the centgener plats in beds by machinery was devised to take the place in the general nursery on the long hill row centgener method previously used in planting wheat and other small grains. While the original experiment has not yet

given definite results, this incidental result has already had wide application in the work of plant breeding as this centgener planting machine is in use by many plant breeders. Thus the careful study of plants by statistical methods, where the plants and their hereditary powers, as expressed in averages for their progeny, are constantly under the close observation of skilled breeders, results in many useful facts being learned incidentally, in many serviceable methods being devised, and in suggestions of needed lines of research which are constantly presenting themselves.

In wheat experiment IV-39, "Breeding for rust resistance", it was found impracticable to determine the relative rust resistance of individual plants, by comparing one plant with its fellow. The centgener method was then adopted of measuring the centgener power or breeding efficiency of the numerous progeny of each of numerous mother plants as a means of discovering blood lines more resistent to this disease, and here this system of numbering and recording was found to be very convenient.

Incidentally, the fact was brought out by thus carefully recording the characters of stocks of known pedigree that some of our best yielding accessioned and the best newly bred varieties were rust resistant to a high degree, showing that while carrying out the general work of breeding for higher units of value per acre we are in practice breeding toward resistance to this dread scourge.

In wheat experiment IV-15, "Does crossing increase variation?" this method of note taking served in taking notes on numerous plats of wheat grown from seeds with different kinds of pedigree. Thus, one plat was grown from the seeds of a single self-

pollinated mother plant, the closest possible sexual relationship. The second plat was grown from bulk seeds of a standard variety--which may originally have sprung from a single mother plant. The third was planted with seeds from a plant resulting after several generations of self-pollination following the crossing by means of hand pollination of two related plants. The fourth was planted with seeds from a mother plant resulting from a recent artificially produced hybrid between two radically different wheats. In all these classes this system of numbering provided for the tabulation of the notes on each plant of each nursery stock and for working out graphic illustrations of the genetic results. Some work has been done in devising new graphic expressions of the facts and laws of breeding and the system of notes used has aided in so recording genetic facts that they lend themselves to lucid statement in writing and upon charts. With modifications, this system of numbers has been found applicable to records in animal breeding and to experiments in the study of heredity as applied to animals as well as to plants.

The application of statistical methods in the study of animal breeding and the liberal use of financial aid for this purpose are greatly needed. Economic considerations, vast in magnitude as well as of large scientific interest, demand that the artificial evolution of animals as well as of plants be more thoroughly investigated. And there is need of a large amount of work in studying the facts to better perfect the theories and plans of breeding and also in devising methods for increasing the values of all economic plants and animals.

SYSTEM OF RECORDS NEEDED.

Those who devote themselves to theoreticallgenetic research, whether as their main work or as an adjunct to the production of improved varieties of plants or breeds of animals, must largely devise systems of records for each specific problem. The method of numbering and recording the lineages and the values of individual plants, of fraternity groups, and of non-related groups, as outlined on subsequent pages under the general title "Methods of Breeding Field Crops" will be found useful to serve as a starting point, or to serve as a basis from which to devise systems of records for each genetic experiment with plants. No doubt these suggestions will be of some aid in devising systems of records for theoretical experiments with animals and in man, and also in keeping lineage and performance pedigrees.

To recognize the genetic unity of families, varieties, breeds and species.

In recording the values of unit characters in individuals, and in mass selection en mass.

In recording the values of individuals with a comprehensive description, as a single numerical statement.

In recording all kinds of lineage relationships as:

(a) Lineage pedigrees.

(b) Centgener values of superior individuals.

(c) Genetic values as shown by parental and collateral relatives.

(d) Performance pedigrees.

(e) Breeding values of individuals, families, varieties, breeds.

In recording performance pedigrees of individuals, families, varieties and breeds distributed to growers.

Plans of records to be employed in genetics research work and in creative breeding should be at once simple and comprehensive, and should easily be adaptable to many conditions. There is especial need of a system of numerical records which will serve as number-names, so that the number is both the name and so related to the series of numbers that all the lineage relationships of all individuals may be shown. Much has been done to devise systems of number-names in animal breeding and later in plant breeding, and recently in engineering. The numerical records must be capable of being written in comparatively few characters with pen or typewriter or printed, and must not require much explanation to be clearly understood, also so as to be easily learned by practice in its use.

Some of the things the number-name records can be utilized in is:

To recognize the individual as a genetic unit.

To recognize unit characters as genetic units, both those of direct economic value and those which serve as distinguishing marks.

The numerical scheme outlined in this bulletin, pages to meets most of these conditions, at least so far as plans here presented are concerned, having been evolved while it was being used in the breeding of about twenty species of plants, and in numerous researches in studying how to breed wheat and other crops.

METHODS OF BREEDING FIELD CROPS.

The world is gradually grasping the full significance of the fact that occasional plants have breeding power of peculiar strength and value. Man is becoming fully aware, too, of the further fact that, by hybridizing, other occasional individual plants with still higher breeding efficiency can be created. The fact that new varieties and new breeds are built up on the blood of a single individual, exceptional in its breeding character, or on the blood of a small number of such individuals, is gaining a place as the mainstay of a working philosophy. The work of finding these

rare individuals or their progeny, of testing the breeding power of these new networks of descent, of segregating and multiplying them as varieties or breeds, and bringing these new stocks into wide use is gaining general recognition. Not only amateurs, scientists, and commercial firms, but legislative bodies are coming to a business realization that selection, and also hybridizing followed by selection, may be employed at relatively small cost to increase vastly the wealth produced from our crops and from our live stock. Not only have the methods of crossing and the methods of selecting out the blood of those parent plants showing highest projected breeding efficiency been worked out in case of many species, but effective methods of multiplying them and of bringing the improved blood into general use have been devised. And in numerous cases new varieties and breeds of higher economic or artistic values have been generally received and advantageously used by producers.

While mercantile, manufacturing, and transportation enterprises are being rapidly placed on a foundation built by scientific research, and on every-day practical facts scientifically collected and classified, breeding and many other affairs in country life are backward. And the great need has only recently been made prominent of efforts to devise systems under which progress may be made more rapidly in the affairs of the farm and the farmhouse.

But a remarkable movement has arisen to take up both the details and the general business problems of farm production and country living. The sciences of agriculture and home economics are gaining general recognition and even legislative bodies are coming to a business realization of research and education in agriculture

and in all industrial affairs. The improvement of plants by introducing new kinds, and by improving all kinds by breeding, is gaining a foothold generally. These methods are of necessity somewhat crude and experimental. They have been built upon the present knowledge of plant life, and on considerable practical experience in plant breeding, which on the whole has been successful and most encouraging. It is hoped that they may be suggestive to private breeders and to public servants who may be engaged in improving plants and that they may serve in inducing others to enter the vocation.

The writers have bred mainly those varieties in the case of which statistical methods are especially applicable, and in this bulletin an effort is made to record the methods thus developed. The necessary artistic skill can not well be set forth. It must, in part at least, come by instinct; by contact with artists, such as Luther Burbank; by practical contact with the actual work of combining blood lines into new networks of descent, studying characteristics, and selecting to desirable new types; and by distributing the newly originated stocks so as to be under the constant review of both those who create and those who use the new creations in plant and animal life. The breeder must recognize the crucial test of wide use, whether of a new scientific fact found, a method or a machine invented, or of a "new strain of blood" segregated or created.

The work of breeding can not all be brought under the formalities of statistical records. The breeder must know the species, the varieties or breeds, the families, the individuals, and must be especially familiar with the unit characters of the forms

with which he deals.

Unit characters are rising in importance as compared with individuals in the study of practical breeding and in the study of heredity and natural evolution, except as individuals as a whole are unit characters. The work of Mendel and the results secured by those investigators who have further developed his methods have done much to enable the breeder to know and make intelligent use of the elementary materials in the species with which he works. In this work of art the breeder uses the colors, forms, textures, activities, flavors, and odors as his materials, and the products resulting are comparable with the works of the painter, the sculptor, and the architect in the complexity of the undertaking, or in the subtle beauty of the things achieved.

Many of the most valuable improvements in clonal and self-pollenated species, and to a less extent in open-pollenated species, often come from chance discoveries made by the interested and trained eye of the mere grower. But systematic records are aids in every line of breeding, and in some cases, as with timothy, wheat, clover and flax, they are wellnigh indispensable. In breeding corn to increase the percentage of oil in the seeds and in breeding alfalfa to increase the viability of the seeds in a northern climate, statistical methods are exceedingly valuable in seeking out the most valuable blood lines. In other cases, as in some ornamental flowering plants, inspection by the trained breeder is the principal agency to be effectively used in selecting. The instinct or skill of some plant breeders is so highly developed that they can eliminate all but the better plants by mere inspection, confining the expense of statistical methods to choosing the best from among

the relatively few of greatest promise. The most highly successful breeder combines with extensive scientific records the artistic knowledge of his foundation materials and the constructive faculty made keenly active by wide experience.

The future plant breeders who can combine the artistic insight, as of Burbank, with highly developed statistical methods, and with these the practical business methods of distribution, will be able rapidly to increase the values of staple crops and originate more pleasing ornamental plants. The artistic and scientific expertness which will develop with extensive plant breeding experience in measuring plant values by statistical methods is certain to add effectiveness to the work of plant improvement. Statistical methods will continue to serve directly in assisting in the selection of more useful stocks, and also in training men in the high art of recognising new values in plants when they encounter them. We shall have as the rank and file of breeders a splendid class of men, and among them will appear some of rarest genius.

NURSERY BREEDING.

With most of our field crops the farmer deals ordinarily with the variety as a whole field of plants enmass, a bin of seeds; in rare cases with the individual seed or plant. We at first accepted the varieties of wheat, timothy, clover, rye, and many other crops as they came to us, with little thought of, or systematic effort directed toward their genetic improvement. We try to eliminate seeds which have poor individuality, but all such selection as the mass-selection of the fanning mill is very slow improvement and may be so slow as to not counteract deterioration caused by the environment.

The Individual Plant.--- Upon entering into the serious work of improving the inherent heredity of a crop, it becomes necessary to center much of the work about the individual plant. Not only must its breeding power be determined as shown by the mass of its progeny, thus to compare the projected efficiency of many plants, but this power must be determined as it relates to detailed unit and especially economic, or artistic, characters. Those plants in which valuable unit characters and blended characters are best combined so as to be projected into progeny of the highest economic varietal value become the quest. We deal with the individual largely that we may secure the blood of the valuable mutant.

In case of hybrid breeding the hybridizing is done as a preliminary. The bulk of the work comes when the quest is begun, usually in the third to the fifth generation hybrid, for individuals in which are best recombined the valuable unit characters of the two or more parental stocks. Once the blood is thoroughly compounded the individual plant becomes a unit, because its efficiency as a

progenitor of a race can be determined. We may use Mendelian analyses in deciding how to recombine the characters of two or more parental forms; and the synthesis may go on under more or less of refinement of method in selecting the choice plants. Yet this is all done in the quest of individual plants to be submitted to centgener tests. This is the first test of genetic-economic value, and field plot tests, milling tests and the crucial test of commercial use by growers, manufacturers and consumers are but refinements and extensions of the test of the projected efficiency in the centgener plots.

In case of open pollenated plants, even where rather narrow breeding is practicable, the centgener test is modified and the breeding power of the mother ear of corn, for example, must be somewhat differently judged. But since this is even more true of the variety test in field plats and in the fields of commercial use, this test of the individual plant fertilized by pollen from a group of its fellows gives a nearly accurate measure of its power to dominate for good or ill in the variety where all blood lines are in constant contest with all heredity brought together in the newly recombined network of descent.

Since mutations are very much more valuable as progenitors of new species, varieties and families than are near-mutations, and since they usually occur only very rarely indeed, exceeding large numbers should be grown that by preliminary, inexpensive methods those individuals among them showing the largest individual variation along desired lines may be expeditiously selected. A careful choice from among these highly developed individual plants,

by centgener tests of their respective breeding powers must then be made so as to discover those which combine with their excellence in individuality also genetic excellence in projecting their own values into their progeny. If the species be often pollenated, trial compounds of the blood of the best mother plants in each generation must also be made so as to continuously discard all weak characters; and the field plat and farm testing of those stocks showing strong tendencies must be carried out; thus comprehensively and in detail seeking strains which give increased values per plant and per acre.

CENTGENER TESTING.

The highly efficient inheritance of the plant from a single seed becomes a unit of interest, as does also the unit character which may have value as one of the coordinated units of the newly formed variety. Great importance attaches to the methods of growing large groups of individual plants so that one plant may be compared with another plant; and of growing and comparing "fraternity groups", so that the progeny of one individual plant may be compared with the progeny of another individual, thus to measure the breeding values, the projected breeding efficiency, the genetic power of the respective parent plants. It is necessary to determine the respective breeding powers of individual plants as they express themselves in the average height, weight, quality, etc., of their progeny. As a matter preliminary to centgener testing of recent hybrid stocks it is necessary also to know of the Mendelian unit characters of the parents and the facts as to how the respective Mendelian character pairs may be segregated and recombined. On the other hand centgener testing of hybrids, as well as of stocks,

not recently hybridized is in large part done broadly, using large numbers and measuring the centgener values in a broad way as expressed by general vigor and especially by quantity and quality of the net product, as of wheat of excelled quality. Where a combination is clearly sought, as in Professor Spillman's wheat, where he combined the hardiness to endure the winter of one variety, the chaff holding power to prevent shelling and the stiff straw to prevent lodging, with the heavy yielding power of another, something can be done at attention to selecting for the actual units. But even here, the selection often settles down to closer centgener measures which decide among the stocks which seem all to combine the desired unitcharacters. The centgener, followed by variety tests, are efficient and delicate means of measuring heredity values.

The management of varieties and species in the nursery varies according to their habits of growth. Species naturally close pollinated require radically different treatment from that necessary with open-pollinated species. The breeder needs to understand the minutiae of the flowering, seeding, and other habits of the species and varieties which he is endeavoring to improve. He needs to know the cultural conditions under which the new variety is to be grown and the uses for which it is designed. In many cases he must become familiar with the process of manufacture from the products of the crop with which he is working, as in case of wheat and sugar beets, and in some cases must have in mind possible new uses.

Fig. ~~8.~~ 14 Selecting the best plants from a foundation bed preparatory to the selection of mother plants.

THE BREEDING NURSERY A BATTLEGROUND OF BLOOD LINES.

The plant breeder is not so particular that the selected plant itself display a high value individually, as that it have the power to transmit superior value to the average of its succeeding generations. Hence it is that the breeder, through the succession of his operations with the foundation nursery bed, where he secures mother plants of superior individual excellence; through the centgener plat, where he tests the breeding efficiency of the respective parent plants; through the field variety test, where he tests the power of the respective varieties to yield values per acre, makes the blood of each plant compete with the blood of each of many hundred other plants for the opportunity of projecting its heritage into the useful variety.

Where the breeding on the one hand simply is a matter of selecting a single mother for a monobasic variety, whether clonally or seminally multiplied, the effort is to find the plant or plants which have the strongest inheritance along the desired line and to eliminate all others. This is possible because the progeny of one plant can be so rapidly multiplied that there are soon clons or seeds sufficient for all growers. In case of some species, as tobacco, the new stocks can be so rapidly multiplied as to supplant the old in a few years.. In case of other species as walnut trees, decades may be required.

A different set of problems is encountered when the breeding, on the other hand, requires not only the selection of open pollenated parent plants with high individual breeding efficiency along the desired line, but the choice of a group of these which

when their blood is interbred generation after generation form a network of descent which as a narrowly or broadly interbreeding unit has high projected efficiency along the desired line.

The Function of Hybridizing.

By selecting we find existing values; by hybridizing we seek to create new values, thus to broaden the field of selection. The function of hybridizing or radical crossing, which is treated more fully on pages ____ to ____, usually is merely an occasional operation in connection with the plant-breeding nursery. Generally speaking it consumes relatively little time. It is an especially delicate operation only in cases of very small florets or floret; and Oliver and others are devising many ways of manipulation so as to successfully cross pollinate even very small flowers. A day's work spent at hybridizing often provides sufficient work at nursery selection to require years of effort and much expense. Nearly the whole of the time and expense in the field crop breeding nursery comes under the various operations relating to selections, as do all which come under field testing and in determining values through the results secured in the commercial use of new varieties.

The function of "crossing" or "hybridizing" is to create the occasional plant needed for still higher inheritance values. When the methods of selective elimination are developed and financed so that the very strongest breeding plant may easily be found and multiplied to take the place of the whole variety, or even to make possible a new industry, creative hybridizing will become a mighty factor in economics and in agronomic art and technology.

A day's work at flowering time among the various crops

hereinafter briefly discussed reveals wonderfully interesting and beautiful performances of the floral organs of open-pollinated species while in the act of cross-pollinating. Beginning with the first rays of dawn the wheat flowers begin their life function of fertilization. The feathery plumes of the stigma glistening from the vertexes of the open glumes stand ready to receive the pollen as the anthers quickly mounting to their full height, topple and cover them with the tiny pollen spores. Following close upon the wheat comes the barley, flax, timothy, bromus, etc. Thus the day passes on toward evening with a gradual diminishing of the increasing quantity of performances until about five o'clock P.M. when the oats and bromus herald their news of fertilization by opening their florets and covering the entire field with a spray of pollen dust.

Many of the field crops are not so visibly active. These are for the most part termed either close or insect pollinated, such as the pea, bean, clover and alfalfa, and fertilize themselves under the cover of their unopened florets. In addition to these two classes there is an intermediate series of which flax is the best example, which appears to be very open to cross-pollination by the wind and at the same time freely visited by insects. But a close study reveals the fact that the process of pollination has been effected before the floral envelope opens. The Plates to and accompanying notes give suggestions as to how a number of species of floral organs may be studied from early blossoming time to the maturity of the seeds.

The whole range of pollination and fertilization of flowers is very imperfectly understood. There is much study and experimentation necessary before the facts are established. The field

offers much interest and honor to those who will devote the thought, time, and patience necessary to a complete discovery of this phase of plant breeding.

Emasculation, the process of extracting the anthers of the flower with which crossing or hybridizing is to be accomplished, may be best done in case of field crops at any time after the plants are "headed out", but best results are attained when emasculation is done the morning before pollination would normally occur. The color of the anthers in most species may be used as an exact indication of the time for this work. An expert can, by opening one or two flowers, tell whether the time is ripe for emasculating. The anthers in the greenish-yellow stage are considered best. Green or yellow anthers indicate an unsafe time, the former because it is difficult to tell how many days the flowers should be left before pollinating, and the latter because the anthers are too easily broken, thus permitting the pollen to escape and cause self-fertilization. When the anthers are removed in the greenish-yellow stage the flowers, as a rule, should be pollinated the first day following. The second day will in most instances also be safe. Perfect fertilization may be effected even as late as the fourth day, but such an extension of time is not to be recommended.

In the preparation of a head, spike, or panicle for cross-pollination one should do as little damage to the flowers "handled" as possible. Without attempting to describe the minute detail of operating on each species, suffice it to say that the operator should first eliminate all rudimentary and stunted flowers, all beards in wheat, and all flowers or parts of flowers not to be "handled", which are seriously in the way and can be removed, with-

out injury to the flowers to be cross-pollinated. Use sharp scissors for this elimination so as to do as little damage as may be. The tweezers used should be forced gently between the glumes or other flower parts in quest of the anthers. If parts of the floral envelope have to be removed to operate properly, as in flax and barley, they should be removed with great care lest injury to the ovary or stigma should result. The same procedure and care should attend the insertion of the pollen. In times when the atmosphere is very dry, of drying winds, especially with some species, as in case of beans, very great care must be used not to seriously increase the exposure of the floral organs to either the drying of the air or to light. In Figures 2 and the instruments necessary for crossing and hybridizing field crops are shown.

In selecting the two or more foundations for hybrids, the species, varieties, and strains or families should be selected with care, and superior plants should be chosen. Often these plants can be found in the field, in variety test plats, in nursery centgener plats, or in nursery foundation beds, or foundation beds can be planted that choice can clearly be made of superior plants to be parents of the hybrid stock, from which varietal stocks are to be separated out by selection.

NURSERY CENTGENER PLAT TESTS AND FIELD PLAT TESTS TO BE ACCURATE MUST BE REPEATED.

The less expensive method of having only one plat in nursery or field tests may be followed, but in many cases duplicate centgener and field test plats are wise, whether in breeding corn, tobacco, wheat, clover, or other crops.

To avoid seasonal differences, favoring one strain as compared with others, the centgener test should be carried through three or more years. The expense can be reduced by throwing out stocks which fall hopelessly low in the first year, or in the first and second years. Likewise, in case of field-plat tests, which are sometimes duplicated the second and third years, some of the least valuable stocks can be eliminated at the end of the second or even after the first trial.

PREPARATION OF LAND FOR PLANT BREEDING NURSERY PLATS.

It is very desirable, especially in breeding crops like wheat, corn, and flax, where "centgener" or other forms of statistical method is used, that land be secured which is very uniform so that each plat is like each other plat, and which is slightly more productive than the lands on which the farmers who are to use the new varieties commercially grow them. After choosing for the breeding nursery the best available land it must be brought under a proper system of cultivation to prepare it for the necessary nursery plat tests. It is often best to have a sufficient number of fields or series of fields so that in two out of three years other crops which prepare the soil for the given nursery crop may be grown in rotation with the nursery crop. A given crop should not be grown in the field until the residual effects of the same kind of crop is no longer prominent in the soil. In some cases a nursery of one species can be rotated with a nursery of another species. But more often the crops placed in the rotation with the given nursery crop should be those crops which when grown in a field way, are known to prepare the soil for good yields of that crop which is to occupy

Fig. 15 A cotton disc used in working up the soil for planting centgener beds. Note that an alley is left. All work upon the beds is done from this alley so as to obviate the horse stepping on the bed. A footprint on a foundation bed would create uneven physical conditions and therefore an unreliable variation among the plants, which would impair proper selection of superior mother plants. Centgener planting machine in the background.

(Have asked Ayer for photo)

Fig. 16 Hoeing and raking nursery beds to make them smooth and level, so as to secure uniform depth and compactness of soils about the seeds that germination may be uniform in all plats.

the nursery. With one or better two intervening years of green manure crops, or even commercial fertilizers can be applied. The application of barnyard manure can be made uniform only with the greatest difficulty and even commercial fertilizers can be applied so as to give each centgener plat its exact share only with great care. Where the land is to be prepared for foundation beds, as of wheat, it is not desirable to have the land made ununiform the previous year by large plants like corn which have locally affected the uniformity of soil conditions. The rotation shown in Figure 40 adopted for use at the Minnesota Experiment Station, illustrates how a seven-year rotation is utilized to accommodate the corn nursery, winter wheat nursery, and nursery of spring crops.

SELECTING MOTHER PLANTS.

Seeking mutating mother plants combines art and science. In case of field crops immense numbers can best be compassed by some such methods as follows:

(a) Plant the parent variety in a very large plat or field under ordinary good field conditions.

(b) When ripe select from strong appearing heavy yielding plants thousands or tens of thousands of heads, spikes or panicles, being careful not to choose more than one fromeach parent plant.

(c) Plant a hill plat, a hill row, a drill plat or a drill row centgener from each of the chosen heads, spikes or panicles.

(d) When ripe, upon inspection, discard all which are clearly not promising. Harvest the promising centgener plats, thresh and clean the seeds, in some cases weighing for quantity and

grading for quality, and discard all but that one to ten percent which give promise of excellence. In this way this first selection covers the broadest possible number of select plants, giving to each an opportunity to show its breeding power in a centgener test. It also insures a goodly number, usually hundreds, which prove their right to further tests of their genetic values as progenitors of varieties. Much depends upon the breadth of the basis from large numbers of select plants used as mothers of centgener plats, that the best mutating plants may be secured. This is next in importance to the selection of superior foundation stocks.

FOUNDATION BEDS.

Plants to be used as parents of hybrids, or as mothers of pure-bred or hybrid centgener nursery plats, can frequently best be selected from fields, but in many cases it is necessary to plant foundation beds, that those individuals which compete most strongly under crowded conditions or become the most highly developed under conditions equal for all individual plants may be there selected. In some cases these foundation beds may be small and the seeds planted so thickly that those fittest to survive under very adverse conditions are chosen; or they may be so planted that each plant has the same area of soil as each other plant or even a larger area. In some cases, as with corn, wheat, rye, and barley, where it is not practicable to transplant the young seedlings to the larger beds which give each plant sufficient room to develop to maturity, thus to allot to it the same room as to each other plant, the large nursery foundation plat is often useful. Dr. Von Tschermak of Austria with much care in separating the straws at the root so as

to secure all culms spring from a given seed, avoids the use of the foundation bed, and thus secures in case of wheat, oats, barley and rye select plants grown in the irrigularly planted conditions of drilled or broadcasted grain in the ordinary field, and uses these as mothers of centgeners.

In case of timothy, brome grass, and other thickly planted perennials, the foundation bed is sometimes useful, that a large number of plants may be grown from the mixed seed of the variety under conditions which enable the breeder to study the individuality of each plant when growing uncrowded in a hill by itself. This is rather expensive, however, and as a rule it would seem the better part of wisdom to select spikes, panicles, or heads from vigorous stools or plants, and enter these at once into small centgener row plats, thus in one or two years to eliminate all but the few with high breeding efficiency and utilize the bulk of the available labor and means on the relatively few stocks which at once by their genetic vigor in centgener plats give promise of usefulness.

Formal investigations are needed to determine the number of select individuals it is necessary to subject to centgener tests in each species and under each condition, as to narrowness or breadth of breeding, within the established variety or within the recently hybridized stock. Even where ears, spikes, panicles or heads chosen from superior mother plants are used in planting centgener plats, the labor can in some cases be minimized in making the first elimination by planting in centgener drill rows, discarding all but the few most promising, and then selecting ears, spikes, panicles, or heads, as the case may be, from among the plants of those respect-

ive rows. In case of such plants as timothy, potatoes and white clover, it seems best to plant the seeds in very small plats, or even in greenhouse plats; and to transplant to the foundation beds, where each can be given ample room, only those plants which show the vigor to shoot at once above their fellow seedlings.

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Fig.~~13~~. A label stake made of one half of a 4-foot lath and a card as used in designating centgeners in the nursery. The I-06-30 designates the kind of breeding (I stands for straight selection, II would mean that the stock is a hybrid.) the 06 is the year in which the mother plant was selected, and the 30 is the nursery stock number, N.S.No. under that year of wheat. The 4001 is the particular centgener number. Below this is the name. The number 973 is the Minnesota accession number, 973, still further abbreviated into merely the number-name, Minn.No.973.

Places for Recording Notes.

The places for recording notes in the breeding of plants should provide for accuracy, safety, ease in referring to desired items, facility in the tracing of pedigrees of notes and of nursery strains and varieties from year to year, and should be easily used in connection with marking seed stocks, or individual plants, in the laboratory, in the seed house, or in the nursery and fields; and should easily be read on the stake labels which mark the growing plants. They should be adapted also to use in distributing new varieties to growers, and to use by seed firms in their catalogues and in trade correspondence. The following is a list of the record books, etc, which have long satisfactorily stood the test of use in breeding field crops at the Min esota Experiment Station.

Books:

Books substantially bound in half leather, 150 to 300 pages, each page 8-1/2 x 13-1/2 inches rules to about 40 lines, and used in series, with notes consecutively arranged.

(a) Accession Book: a book for newly introduced varieties of each species or each group of species, the stocks of seeds to be entered successively as received from the breeding nursery or by introduction, as Minn.No.1, Wheat, Minn.No.2 Wheat, Minn.No.3 Wheat; Minn.No.1 Corn, Minn.No.2 Corn, Minn. No.3 Corn, etc. See Fig.14.

(b) Nursery Yearbook: in this are recorded all facts concerning foundation beds, centgener plots, and other nursery plats; in series by years: Nursery Year Book, 1908; N.Y.B. 1909; N.Y.B., 1910; etc.

(c) Field Yearbook: in this are recorded the planting, field thrashing, and general laboratory notes of the variety tests. In series of years: Field Year Book, 1906; F. Y. Book 1907; F. Y. Book 1908; etc. See Fig.15, blank form in Minnesota Field Year Book on which to record variety tests of wheat.

Loose Leaf Records and Blank Forms:

A loose leaf system is also used for such portion of of the records as best lend themselves to loose sheets. (See pp.).

(a) Cards or loose sheets, ordinary business letter sheet size 8-1/2 x 11 inches, or other suitable uniform size. When desired, punched to fit vertical filing cases. May be ruled with blank forms adapted to recording and summarizing records. (See pp.).

(b) Blank forms mimeographed or printed on the outside of envelopes, as envelopes 6 x 9 inches in size, used as seed packets for harvested seed heads. These are made upon special order of tough linen paper and carefully glued with special glue which will withstand damp weather. (See pp.)

(c) Ledger sheets especially ruled for tabulating records of yields, laboratory tests, etc. (See pp.).

Label Cards:

Label cards 2 x 4 inches, to go in label holders on 1/2 bushel iron boxes, or to be fastened by tacks on stakes in the field. The cards are made of card board, marked with stub pen using India ink; and if for outdoor use dipped in melted paraffine of good quality (70 ¢ hard). (See pp.).

Stakes:

(a) Stakes 1 x 4 inches or 1 x 6 inches and two to five feet long with letters painted on, or with paraffine cards tacked on, are used to mark nursery series, field variety test plats, increase plats, fields of grain, forage or root crops. (See p.)

(b) Stakes of lath, two or four feet long, with cards tacked to the stakes for the small nursery and field plats are inexpensive and very convenient. (See Fig.13, p.)

Seed Distribution Records:

In these are recorded the general facts concerning the distribution of valuable new varieties, giving addresses, dates, amounts, and varieties and providing for results of reports from those who become station cooperators by growing the new pure-bred varieties for sale.

(a) Card index lists of persons recommended as growers of pedigreed seeds; with headings for keeping a record of varieties sold them, and their efficiency as distributors of pedigreed seeds and plants. (See)

(b) Loose-leaf scheme of keeping an account up to date of stocks on hand and available for distribution of each variety. (See)

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Fig.~~17~~. "Wheat Accession Book", open on the left hand; and "Field Year Book", closed on the right.

(Retouch on side of books)

Field
Year Book
1907.

(c) Triplicate blank seed order books: with one order to be retained by the seller, one to go to the transportation company, and one to go from seller to purchaser as a receipted bill. (See Fig. 16).

(d) Blank forms to be supplied to growers, that they may systematically comply with request to give results from comparing new varieties with other varieties grown under the same conditions.

Records of Theoretical Experiments:

The arrangement of plats and the numbering system of stocks, individual plants, nursery plats, and field plats herein given may be advantageously used in many theoretical experiments. In many cases the blank forms provided for the work of producing can be used in the theoretical investigations. Such other blank forms and systems of records as are needed for each experiment will best be devised by the experimenter for each specific line or inquiry.

Professor C. A. Zavitz of Ontario Agricultural College keeps his notes on sheets of foolscap size, and simply ties them together at the upper left hand corner with a metal fastener. To protect these when carried to the field he has flat tin boxes into which they may be laid. The boxes are in inch thick with covers with rims fitting down over the sides, thus protecting the papers in case of a sudden rain storm.

(In draughting room.)

Fig 19.

Foundation Breeding Stocks.

The plant breeder should secure as his basis for foundations of new varieties the very best available kinds of a given species. In many instances more than half the gain to be made by the breeder within the first decades comes from securing superior varieties to start with. In very many cases the best available foundation stocks have been already introduced and are to be found in the region in which the improved plants are to be produced. On the other hand, the locality should not be alone depended upon for stocks to begin with, but both local and imported varieties should be secured and placed in variety field tests, that those yielding most value may be secured.

The ways and means for introducing into new localities varieties from other states or from foreign countries have been so well organized by the offices of Foreign Seed and Plant Introduction, and Seed Distribution, of the United States Department of Agriculture, in cooperation with the State experiment station and other agencies concerned with plant improvement that any experimenter desiring to secure new stocks from any part of the world need have no serious difficulty in doing so, provided he can show that suggested importations are likely to lead to important results.

The experimenter should make a most careful study of the varieties already succeeding in the region for which he desires to produce forms of improved plants. He should learn of their economic characteristics, and of the lines in which improvements are needed to better meet the conditions of soil, climate, method of cultivation and uses; so as to secure larger yields and less expensive

methods of production, also to make improvements in the quality of the product, and to adapt them to the manufacture of new products.

By correspondence, and possibly by travel, and by asking for the assistance of those public agencies devoted to plant introduction, facts can be learned as to the existence in other regions with similar conditions of climate and soil of promising varieties of the same species. Some of these may at once prove better for use; while others may serve as foundation stocks from which superior selections may be made. They may also serve for hybridizing with common varieties, or among themselves, to thus produce hybrids from among which may be selected parent plants of even higher value than those to be secured from among the plants in the original varieties. In seeking foundation varieties it is often wise to seek those which have some special quality which other foundation stocks lack, that, by hybridizing, the desirable characters of the two may be recombined into one new variety. The discoveries of Mendel and others who have used his methods of investigation have greatly increased a faith in ultimate achievements through hybridization. While these discoveries have not relieved us of the necessity of producing very large numbers of a given hybrid in order to secure the one, or the few, parent plants which combine with great individual excellence the power to project the new values through their progeny into a valuable variety or breed, yet they both increase our hope and doubly assure us that the newly created combinations may be as stable as were the old varieties. The results of these researches also lead us to hope for more light from further investigations in the laws of heredity.

Very often the person or institution starting into the breeding of a given species of field crop can best start with a variety, or even an excellent mongrel stock known to do well on his own farm or in the fields of other farmers in the vicinity. With this he can gain experience and often from it he will produce the first improved stocks worthy of sale and distribution. Other promising varieties should also be secured at the beginning and grown in competition; that in a few years the best may be chosen as foundation stocks. In case of an open pollenated species, as corn, the farmer or institution with only a moderate sized farm should generally limit the breeding to a single variety; but in case of species reproduced vegetatively or by self fertilized seeds numerous varieties can be carried forward without the mixing of their pollen.

The United States Department of Agriculture, the State Experiment Stations, committees of State and national breeders' associations, and experts in the breeding of the respective species are ever ready to respond to requests for advice as to how to secure foundation varieties with which to begin breeding, or varieties to be used in hybridizing. The Office of Seed and Plant Introduction of the Bureau of Plant Industry of the United States Department of Agriculture is equipped to serve breeders in securing from any part of this country or of the world stocks needed in plant breeding.

The breeder should make wide inquiry for facts as to breeding each species which he proposes to improve, and it is often wise to collect and to grow in small plats numerous varieties of the species with which work is being done, that the habits and limitations of its various forms may be known. In many cases prelimin-

ary hybridizing should be done to become thoroughly acquainted with the character pairs and the way in which characters may be recombined, as well as to gain manual dexterity in handling them. The work of determining character pairs and their recombination is rapidly becoming so important that public agencies for performing these preliminary analytical genetic studies and recording all proven recombinations in animals as well as in plants should be established under some central authority, such as the Bureau of Biological Survey of the United States Department of Agriculture.

In many cases expert breeders can, and will, freely give most valuable advice as to why one variety or group of varieties promises very much better to serve the breeder's particular purposes than other varieties.

And the testing of varieties to determine which promises to be the best foundation stock, should be thorough as to care in giving each variety under trial an equal chance with the others, and the testing should be continued sufficiently long to give definite comparisons. Often a variety is so modified by "place effect" that the yields and quality from trial the first year should not be considered. Three years tests with seeds of annual crops grown in the vicinity will usually determine differences in value, and marked differences can often be determined at once, so that no further expense need be wasted upon varieties clearly not useful. Thus in many cases the seeds of newly introduced varieties may be grown the first year; and the real tests be made the second, third and fourth years. Many varieties will be discarded the second year, and even some will do so poorly the first year that they need not be entered

into the regular tests. The third year still others can be discarded; and, based upon the averages of three regular tests, the choice of varieties to be used as foundation stocks may be chosen at the end of the fourth year.

In case of open pollenated species--as corn, cotton, clover, rye, etc--the seeds grown in adjacent field test plats can not be used to plant the plats the next year, because of crossing among the plats. In this case the breeder should grow each variety on a separate field, or have it grown on another farm in the neighborhood, that uncrossed seeds grown in the neighborhood may be available for planting the variety test plats; and, if needed later, from which to multiply for distribution the variety which proves best. In many species as clover and rye, the seeds locally grown the first year can be preserved in a dry place so as to serve in planting the variety test plats for the three successive years without the expense of seeding a separate field each year. On the other hand, in case of an excellent variety, a neighboring farmer will often be found who is willing to profit from growing a superior new variety from which the breeder desires fresh seed annually.

Choose Well-Developed Rather than Primitive Forms.

Breeders who choose wild and primitive forms as their main foundation often make a mistake, especially if they seek quick returns for their labor. Where results must quickly accrue to justify the expense, it is generally wise to choose that variety commonly grown in the vicinity and make improvement in it by selection; and also to choose two very similar good varieties and hybridize these, and by selection find the best blood in the new hybrid; and thus,

by working along conservative lines, make hybrid varieties, or secure widely separated stocks of the same variety and cross them thus to produce foundation stocks from which to secure superior mothers or groups of mothers of new varieties.

On the other hand, those public agencies and private parties who are prepared for long waiting and large expenditures of labor and money can find innumerable lines of more or less radical hybridizing which offer almost unlimited opportunity. Not only can varieties be produced which will improve the quality and make cheaper the production of all staple plant products, but new species may be created, and varieties may be developed which will make possible the production of a crop heretofore impossible under a given condition, or will have qualities from which new commercial products may be made. Thus some breeders believe they can produce heavy yielding hulless oats, possibly with special flavor, to be used in making oatmeal. Varieties of flax have been produced which grow tall enough to produce long line fiber upon which to establish a linen industry in regions too dry produce long flax fiber with the heretofore existing varieties. The Vilmorins and their successors so increased the percentage of sugar in the sap of common beets and the yield that a great sugar beet industry has resulted. It seems possible to produce red clover which will thrive under the warm climate of some Southern states, and cowpeas which will ripen seeds and thus be a practical hay crop far to the north. Dent varieties of corn are being developed for cold regions north of the corn belt and alfalfa for humid regions in the Eastern states.

Receiving, Numbering and Naming Stocks.

A good system for numbering stocks of varieties is important. There is a strange fatality in the mixing of seeds of varieties where two or more kinds of a given crop are raised on a farm. Farmers who grow two or more kinds of any grain have great trouble in keeping names from being wrongly placed, especially of varieties similar in appearance. Seed dealers and private breeders of pure-bred plants have much trouble in accurately keeping all their plants and seeds correctly labeled, so that only those true to name may be supplied to their customers. Public agencies which import, breed and distribute plants are under the greatest necessity of accuracy in sending out only seeds and plants true to name and true to described types. Great care is needed also to avoid the introduction of new diseases and new species of weeds. There is necessity in experiment stations of being sure that varieties tested and reported upon are true to the names under which they are tested.

The system of number records hereinafter described was devised under the needs of the work of importing new stocks and of breeding, testing, and distributing imported and newly originated selected and hybrid varieties of about twenty species. It contemplates the use of bound books with fixed leaves, such as invoice or "accession" books, "field year books", "nursery year books", and "variety ledger books", mentioned above, which serve as keys to all records of varieties, plats and laboratory tests, and to all histories of accessions and to all stocks distributed. It provides also that the bulk of all current notes, records, tabulations, and summaries be recorded under the loose card or vertical filing sys-

tem.

The plan here presented, after having been in the formative stage for a decade, has now been in extensive use for a decade without further material modification. Other plant breeders working with other classes of crops have developed other systems suited to their needs. It is hoped that these may also be published. The plan here outlined forms part of the basal part of a system of bookkeeping in breeding and highly accrediting new plants. Many of its elements ere originally drawn more from animal breeding than from plant breeding, and the comprehensive modifications here developed will in turn be of value in better organizing record keeping in animal breeding. It has many elements useful in keeping records of theoretical studies of heredity in plants, animals, and men. More comprehensive and simpler number systems of records in animal breeding and in human genealogies are much needed.

It is believed that the plan here outlined has in it many of the elements needed in a general system for permanent use in breeding all the species of plants, and in animal pedigree records, and also in human genealogies. It recognizes the individual as the unit, and provides means for tracing lineages of all families, strains, varieties, and breeds, regardless of their origin. In plant breeding it provides a simple means of following the progeny of a single parent plant, of a group of parent plants, and of the resulting varieties, as they pass through the steps in the nursery breeding to field trials and to distribution to growers. In also conversely provides means of marking the "invoice" brought into the establishment from the outside or from other plant breeding nursery,

and of so recording the cultural and breeding record of each stock, that all references may easily be traced back to the exact historical invoice as entered in the "accession book", or to the parent plant in the plant or plants breeding nursery.from which the new variety descended.

But most important of all is that it supplies a method of recording the "projected breeding efficiency" of each plant used as a parent, by providing a plan of records of the average value of the progeny of the respective parent plants whose progeny are under comparison; and of recording the average value of each resulting new variety tested in the field and factory. It was devised to enable the breeder to use systematically and effectively centgener tests and variety tests both in discovering the strains with high values, and to supply organized and highly authenticated records to be used in distributing varieties with proven values. Only in very rare cases in recent years has it been found necessary to modify the system to meet new conditions.

Giving Varieties "Accession Book" Numbers.

Varieties secured from outside sources are called "accessioned varieties"; varieties originating in the nursery, if originated by some form of selection without bringing in other blood, a re called "selected varieties"; varieties originated by first producing hybrid stocks and then selecting out the valuable strains which in the nursery have gained the right to advancement to field tests are called "Hybrid Varieties". These are all given variety numbers in the "accession books", each variety taking the next consecutive place in the numerical series of the species. The sources and other

facts concerning these varieties are recorded in the variety accession book as shown in Table . The accession numbers, and the historical nursery numbers of newly bred varieties, in these Variety Accession Books are clearly connected by means of reference numbers with the records in the Field Year Books and the Nursery Year Books mentioned in other pages.

Accessions from outside sources and new varieties introduced from the plant breeding nursery are thus entered in separate books called "Wheat, Minn.Accession Book"; "Corn, Minn.Accession Book"; "Bromus, N.Dak.Accession Book"; "Flax, N.Dak.Accession Book"; or "Barley, Wis.Accession Book", etc, as adapted to use in the respective state experiment stations. This plan contemplates that an accession book shall be kept by each firm or experiment station, or even by each bureau or division, and that each species of crop shall have a series of numbers beginning at unity, thus: "Minn.No.I corn"; "Minn. No.2 corn," etc. In case of the state experiment stations, the names of the State, abbreviated as above, have been found very convenient to designate the accession books and the numbers of the respective varieties. If large numbers are to be dealt with, it is wise to have a separate book for each species. Sometimes it is convenient to have the book containing the records of one species in one room or in the field, and the records of another species in another place, as two persons may need records at the same time.

Data Recorded in Accession Books.

In the accession book general facts as to source, name, date of accession, etc, are placed in tabular form; also a form is provided under which the varieties may be specifically described.

See sample pages, Table . In addition to this, descriptive cards, like that outlined by Mr. C. S. Scofield for wheat in Bulletin 47 of the Bureau of Plant Industry, United States Department of Agriculture, also like those devised by Mr. W. W. Tracy of the same bureau, for vegetables, are being used to advantage with each species.

It is very convenient to have these notes in the Accession Book where they are not on loose blanks and where they may be sometimes

(In draughting room)

Fig. 20.

used for reference in the seed storehouse and in the field. The Accession Book with fixed leaves thus serves as a key to all files, whether in books or in vertical filing systems and for this reason this one set of records should be in bound books. The technical description cards may also be carried to the field, if necessary, preferably protected by tin box covers, as mentioned on page . Vaults for storing and great care in protecting books when not in use, at experiment stations, are necessary to insure the preservation of these notes, which become the authentic pedigrees of varieties, some of which prove themselves worth many millions of dollars. The briefer description in the accession book may be made up from notes recorded on technical description cards in the supplemental loose card fertical filing system.

MANNER OF PLANTING NURSERY PLATS.

The best depth to plant seeds in the foundation beds and in the centgener plats in the plant breeding nursery, whether broadcast in drills, in hill rows or in hill plats, the amount of seed per acre, the distance apart for the hills, the number of hills in the foundation bed and in the centgener plat, and the width for alleys about the plats, are matters of detail which experience has at least partially determined for a number of species. The following table will serve as a preliminary guide to the beginner in case of species with most of which the writers have had experience in Minnesota.

Table 4. Depths and Distances for Planting Hills in Nursery, Centgener Plats and Foundation Beds When Single Plant Hill Planting is used, also Amount of Seed Sown when Broadcasted in Fields./

Crop.	Depth.	Seed per acre, drilled or broad casted.	Distance apart when thinned to one plant per hill.	Width of alleys between centgener rows or plats.
	Inches.	Pounds.	Inches.	Inches.
Alfalfa	1 to 2	15 to 20	24 x 24	48
Cotton	2 3	....	18 x 45	..
Barley	2 3	120	4 x 4 to 6 x 6	30
Beans, field	3	....	18 x 18	36
Beans, soy	2 3	....	18 x 18	36
Beets, mangel	1 2	....	25 x 10	28
Beets, sugar	1 2	....	20 x 8	20
Beets mother roots	a	....	36 x 36	20
Bromus	1	18 24	36 x 36	12
Buckwheat	2 3	....	6 x 6	..
Clover, alsike	1 2	3 5	24 x 24	48
Clover, crimson	1 2	....	24 x 24	48
Clover, red	1 2	6 10	24 x 24	48
Clover, white	1	3 4	60 x 60	10
Corn	2 4	....	42 x 18 to 48 x 24	42
Flax, for fiber	1 3	35 45	4 x 4 to 5 x 5	120
Flax, for seed	1 3	120 160	4 x 4 to 5 x 5	120
Hemp, for fiber	2 3	... .	8 x 8 to 12 x 12	30
Hemp, for seed	2 3	....	8 x 8 to 12 x 12	30
		also 6 or 8 seeds in hills 5 x 7		
Ky.Blue Grass	1/2	2o 30	36 x 36	60
Millet	1 3	....	4 x 4 to 6 x 6	b
Oats	2 3	64 90	4 x 4 to 6 x 6	30
Tobacco	......	....	42 x 18	42
Peas, cow	2 4	....	36 x 36	60
Peas, field	3 5	120 150	36 x 36	60
Pumpkins	2 3	....	96 x 64	180
Rye	2 3	120 140	4 x 4 to 6 x 6	120
Sorghum	2 3	....	42 x 6	...
Timothy	1 2	10 12	18 x 18	60
Wheat	2 3	75 120	4 x 4 to 6 x 6	30

a Mother beets should have top carefully twisted off, not cut, and crown should be left well above ground in planting out the root in spring.

b Alternate with plats of spring grain or flax, so as to avoid much cross pollinating.

(Send a copy to each specialist for revision and completion of amounts, etc.)

Planting Centgener Plats.

In breeding many species there is great advantage and even necessity in so planting that the individual plants, the product of single seeds, be each placed in a separate hill, that each plant may be under similar conditions and may be separately studied and harvested and its values recorded. Not only is it desired that the individuality of the respective plants, all grown under equal opportunities, may be measured and recorded; but it is highly desirable that the plan provide for so planting a group, as 100 plants, more or less, from each mother plant of wheat, corn, tobacco, sugar beet or other variety, that the value of the average progeny may be secured as a measure of the value of the inheritance of the respective mothers. The word centgener, of one birth, and the expressions centgener tests and centgener values were devised to crystallize the idea of thus testing and recording the power of individual plants to project their own values into their progeny, that these with highest projected efficiency along the desired line might thus be sought out and their blood used in making new varieties.[a] In other words, a plan of planting, numbering and recording facts and values is necessary under which records may be made of the performance of individuals and also of the breeding power of individuals. Species differ so widely in the room required for each plant; in the depth to which the seeds should be planted; in the time of planting; in the time of flowering; whether open pollinated, insect pollinated, or self pollinated; as to whether propagated by different vegetative parts collectively called "clons";

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a Since the use of the word centgener is often taken too literally, see Glossary, page .

Fig.18. Nursery Centgener Planting Machine. One man sits on the machine holding in one hand a vessel containing the selected seeds for the foundation or the centgener plats. With the other hand he places one seed in each of the 14 cups carried on a long frame. He tips the frame over, depositing a seed in each of the 14 funnel tubes which extend a few inches into the soil. After the row of 14 seeds has been dropped through the tubes the attendant with the lever draws the machine forward 4 inches; the tubes 4 inches apart and the 4-inch forward movement of the machine thus cause the seeds to be planted in squares, one seed in a hill, with the rows 4 inches apart each way. The machine can be built with any desired width between the check-rowed hills. An 8-inch machine is now used in Colorado, but generally 4 or 5 inch machines are preferred. The truck can be built of 2 x 10 plank in short sections which are easily carried forward, and should be provided with stakes at the foremost end.

(Ask Keyser to supply description of their improvement.)

Fig.19. Tented Nursery Centgener Planting Machine. This is the same machine as shown in Fig.18, with the addition of a canvas cover. Since there is great difficulty even with one or more of these machines to rapidly plant large nurseries at the most seasonable time, it is desired to plant during windy as well as during calm days. The cover makes it possible to keep the force of helpers busy during all days when the soil is not too wet.

Specifications for making this machine can be secured upon application. It is now in use at a number of experiment stations and private seed breeding establishments, and is constantly being improved upon. Any one wishing to build one, or to have one built should have advantage of the latest improvements. Having been devised with the aid of public money, it is not patentable, but is public property.

Fig.20. Perforated Centgener Planting Frame. With a small stick the seed, one of which is dropped in each hope, is thrust to the desired depth.

Fig. . Foundation bed planted one seed in a hill by means of the centgener planting machine, showing two outer rows cut away, thus limiting the selection of mother plants to the ten inside rows.

In draughting room.

or seminally by seeds; whether annual, biennial, or perennial; and also in required methods of cultivation, use, etc., that each species must be separately studied and a practical method of plant breeding worked out for it.

Hill Planting Often Desirable.

In such crops as wheat, oats, flax, etc., the effort when placing one plant in a hill has been to have the plants in the nursery at that distance apart which is best for a very good crop planted under field conditions. In case of foundation beds from which to secure high-yielding mother plants it is necessary to have each plant given sufficient room that it may produce an abundance of seed to plant the next year a centgener plat of the desired size. In some cases, where it is desirable to crowd closely foundation beds or to choose mother plants from thickly planted fields, it is necessary to multiply the seeds from a given chosen mother plant for a year to secure a sufficient supply to plant a centgener plat, especially if it is desired to reserve a portion of the seeds, as in the case of some open pollinated species. In case of some open pollinated species, as corn, where crossing in the nursery cannot be avoided, seeds from the original mother may be reserved to plant the centgener plats for the two or three successive years; and yet another portion of the original may be reserved pure to be finally separately planted and multiplied from any mother plant the seeds of which are proven of especial value. In case of such crops as peas, it is often necessary to plant much further apart in nursery plats than would be ordinarily desirable because of the fact that they are inclined to twine together and would make note taking and harvesting separately wellnigh impossible.

Head to Drill Row Often Economical.

On the other hand, as shown by Norton and others, the best way with many crops is to start with a single head, panicle or spike selected in the field from each of many mother plants, planting very short centgener drill-rows or hill-rows, or even a hill-plat centgener plats. This plan often has the advantage of providing the widest possible basis for the selection of mother plants, that is, the entire field from which the mother plants are chosen, and at once puts to the centgener test in a most simple and inexpensive way large numbers of mother plants. Thus the first year ten thousand superior heads of wheat can be chosen from as many plants in a strong field of standard wheat or from a rather newly created hybrid stock, and the second year in five-foot drill rows the seeds from all but a few hundred of these nursery stocks can be discarded upon inspection. Seeds from these reserved nursery stocks can then be placed in centgener competition in 17-foot hill rows or 17-foot drill-rows for two or three years, the best stocks to be taken forward to field test plats.

Border Rows and Cross Alleys.

In foundation beds and sometimes in centgener plats, more especially in theoretical experiments, it is often desirable to have border rows which can be removed, thus eliminating border plants which have more room than those in the interior of the plat but which serve while growing to create uniformity of conditions within the plat. In foundation beds of wheat and other grains planted 14 rows wide, two rows can be harvested from the edge of the outer sides of the plat before beginning to eliminate for the

Fig.13. Scheme of planting wheat in field crop nursery. Light circles represent plants of the variety under experimentation. Dark circles represent two rows of another kind of wheat called "border rows", separating the plats from the alleys and from each other. Where there is no special reason to have a different variety the border rows and the two cross rows A to A and B to B between plats are planted of the same variety as the plats, and may or may not be cut out before harbesting the plat.

selection of the best individuals. In experiments on the theory of breeding it is sometimes found convenient to plant 12 instead of 10 rows across the plat in each centgener plat, that the last two rows may be clipped out when the plants are ripened, thus leaving cross alleys between the plats that each little plat may stand out definitely by itself, making note taking much easier and the comparison of one plat with another more accurate. See Fig. .

The System Easily Learned and Useful.

Assistants, foremen, students and workmen have readily learned the system of planting herein outlined, and it has served as the basis of the very helpful bookkeeping method keeping record of an extensive system of work on Minnesota's University Farm, meeting general approbation; but fully to understand its use, practice is necessary.

The private breeder or the experiment station official who will install this numerical system will rapidly learn the details from his own work and will become expert in using it as he proceeds from detail to detail.

As in all other record systems, data must be put down at the time in their proper place and accurately. The system is not intended to do the work; it merely serves to provide places for recording each fact and methods to serve in classifying, assembling, averaging and displaying the essential facts and results.

By means of such a record system the plant breeding establishment can be indefinitely enlarged, by adding units, as is done in enlarging a manufacturing plant.

Art Must go with System.

There is danger of neglecting the art of the trained plant breeder's eye and of depending too much on the system. Both art and records of performance are necessary and only a large and highly organized plant breeding establishment with workers trained in both the statistical routine and in the art of rapidly eliminating undesirable forms and in seizing upon "new indications of promise" can adequately cope with this problem in which very many millions are annually at stake.

Record Too Many Data Rather Than Too Few.

In developing this system in the work of practical breeding and in theoretical studies of breeding, several times as many notes were annually recorded as are now deemed necessary. The various examples of entries made in the blank forms presented, in a general way express the amount of note-taking and of records which may be used as occasion may require, but only the essential parts of which are in most cases necessary or are used in any given case. See Figures , , , . Each blank form contains more box-head blanks than are taken as a rule in any one line of breeding or in any theoretical experiment. Where an experiment or a line of breeding has settled down to permanent lines only the specific box heads needed should be collected into specific blanks so that the line of notes may be very definitely apparent at all times. However, each breeder must judge as to the amount of notes which it is wisest to take in each given case. It is wiser to err on the side of taking too many notes than too few, though it is better to undertake the breeding of too few species with a given amount of time and money than of too many. In some cases it is wise to start work

with more species to aid in securing means with which to work with them later, and especially that foundation stocks and experience may earlier be secured.

Preserve Old Stock Seeds.

Experience has demonstrated the wisdom of preserving the samples of many foundation seed stocks with which work was begun, and also samples of stocks representing steps of marked progress, especially in work carried on to develop the theory of breeding. Even if the public official does little along lines of research in breeding, his stock of seeds and plants with their extensive pedigree relationships recorded are often in demand by others working out the fundamental scientific facts of heredity and breeding. On the other hand, many records and many stored samples add to the expense, and when necessary stored seeds must be heroically thrown out.

Names and Numbering Systems for Plants and Varieties.

In the breeding of field crops it has been found wise to keep track of all stocks by a system of numbers, proper names being used as additional means of designating those stocks found worthy of commercial distribution. The numbers greatly assist in keeping an historical connection between performance records of good foundation stocks of individual plants in the nursery, and of new varieties which spring from them. The numbers serve as the framework of the pedigrees. Proper names given varieties in addition to variety numbers have an especial value in introducing commercial varieties and are given to varieties which win the honor of being distributed

to growers. In like manner a rectangular plat of one hundred plants can be marked with a single stake and the numbers can be so recorded that each hill or plant within the plat will be provided with an individual number which may be attached to it when growing, and to its seeds or to clons taken from it. This plan of numbering is suited to the needs in breeding perennials as well as annuals, also to breeding fruit and forest trees as well as to such small plants as wheat or potatoes.

Nursery Stock Numbers.

Between the series of numbers designating single plants in the breeding nursery and the series of numbers designating a field variety a third class of numbers has sometimes been found very convenient. Thus large numbers of mother plants are chosen that their breeding power may be tested and from each of these a hundred or more young plants are grown, for two or three successive years, in a drill-row or hill-row or in a rectangular hill plat all carefully planted at a given distance apart, or even sown in one or more drill rows or broadcast in a rectangular plat, or even in several of these plants. While these stocks are thus in centgener plat tests they may not be given variety number names nor variety proper names, but are designated under series of numbers called Nursery Stock Numbers. Thus we have Nursery Stock No.1, 2, 3, etc, of wheat; Nursery Stock No. 1, 2, 3, etc., of flax; etc. The nursery stock number is followed by the year in which the mother plant chosen for the nursery was grown; and reads as follows: Nursery Stock No. 17, 1904, flax; or abbreviated, N.S.No.17 -04, flax.

On the other hand, especially where comparatively few new stocks are started from mother plants, as in the breeding of apples where the cions are tried from a relatively small number of mother plants, this intermediary series of numbers is not so necessary. In this case the inconvenience of a large series of variety numbers would not be especially good, and all stocks could be entered in the accession book under variety numbers.

Under the regular course of breeding a variety comes to the breeding establishment under a name from the seed dealer, or perchance under a number from another plant breeding establishment, or from the Division of Plant and Seed Introduction at Washington, D.C. It is entered in the Accession Book and given the next serial variety number for that species. During its period of trial in field tests it retains the serial accession number under which it was thus entered. If, upon its proving a useful variety, seeds are chosen from it to plant foundation beds in the breeding nursery, the system of numbering provides that each resulting plant may have a nursery number. Thus a nursery plant number may be the first plant of the nursery plat 701; or it may be a plant further along in the plat as 771, 793, etc.

And when any of the plants grown in the foundation bed, or in the field are selected as mother plants and are entered in centgener tests, the resulting centgener plats are given nursery stock numbers, or number-names, which to all intents and purposes are temporary proper names. This number serves partly as a matter of convenience, especially when a nursery stock is subdivided, and partly as a safeguard against error.

When small centgener drill-rows, hill-rows or rectangular plats in hills are planted the next year from seeds of these mother plants, the resulting plants all trace back to the number-name of the parent plant, and if so planted one seed in a hill that each produces a separately grown plant, this plan of numbering provides that each plant may have a nursery plant number. This would seem both unnecessary and burdensome detail, but it is often a useful plan, especially in theoretical experiments, and sometimes in regular breeding for economic results. In most of the work of selecting mother plants and in centgener testing the individual plant numbers within the plat are never used. But the existence of a general plan under which they might be used causes no confusion, nor on the whole requires extra clerical work.

Thus in the nursery there is placed at the head of each centgener, drill-row, hill-row or hill plat, a number which is really both the nursery number of the first plant of the plat and serves as the field number of that plat. Under this initial number enough numbers are allowed so as to afford a number for each separately planted plant in that plat. Thus in a plat with its first plant numbered 701 and containing one hundred or a fraction of one hundred plants, the initial number on the next plat would be plated at 801, and that would be both the number of its first plant and the field number of the plat itself. So that the number of each successive plat may begin with an even hundred and one, (1011, 201, 701, 1601, etc), the plat numbers going forward by the even hundreds. Likewise if plat 701 had 137 plants the first number of the next plat would jump two hundred or to 901; or if plat 701 had 300 or even 285 plants the next plat would begin with 1001, etc.

Under this system of numbering individual plants, centgener plats, nursery stocks and varieties, (as in variety tests, as well as in case of disseminating varieties to growers, and in their use as foundation stocks in the production of selected or hybrid varieties), it is often found convenient to record the year in connection with nursery plant numbers, the centgener plat number, or the field plat number.

Thus Nursery No. 781 -'08 wheat, designates that individual wheat plant which grew in hill 781 in the centgener row or plat beginning with 701 in the year 1908.

Likewise this same centgener plat may have originated from plant Nursery No. 1374 - '07 in the foundation bed in 1907, or may be from mother plant 1781-'07, from which a head, for a head-row centgener test, was chosen from a plant in the field in 1907.

The progeny of a given plant, as 1374 in 1907, may be given a Nursery Stock number to serve as the number-name of the stock arising from it as long as it is not promoted to the field test trials. If its nursery stock number were 41 it would be written N.S.No.41 - '09, wheat, giving the year when the seed actually labeled was grown.

The system of numbering devised at the Minnesota Experiment Station provides a series of numbers, or number-names, for the varieties of each species, thus: Minnesota No.1 corn; Minnesota No.2 corn; Minnesota No.3 corn. Minnesota No.13 corn, having proven best among varieties tested, was widely distributed to growers beginning a dozen years ago without name other than its number-name. In wheat the series runs Minn.No.1, 2, 3, etc., to a thousand and

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more. There is similarly a series for timothy varieties, Minn.No. 1, 2, 3, etc. In like manner Wisconsin has numbers Wis.No.1 corn; Wis.No.2 corn, etc.

Varieties secured from outside sources and varieties which, having been developed in the plant breeding establishment, have shown that excellence in the nursery which gains for them a chance in the field test plats, are each given a number as above. Whatever name they may have had is also recorded in the Accession Book as the parental name. Thus a variety which won the highest record for value in the variety tests and was chosen to be distributed widely to growers under a proper name was the new "selected" variety of flax known in the field plat tests under the cognomen Minnesota No.25, was given the additional commercial name Primost. Dealers and farmers seem to have preferred the number-name, and the variety generally goes under the mame Minn. No. 25 flax.

Giving Individual Plant Numbers.

When seeds or plants are singly planted in the plant breeding nursery each is provided with an individual number, as is a pure-bred animal in the breeder's herdbook, or in the national pedigree registry of the breed to which it belongs. This is accomplished by so plotting in rows, or in rectangular plats, with the single seeds or plants all planted at a given distance apart, that the hills are numbered. Under this plan in case of wheat or other similar crop a stake marking the first plant of a row of one hundred plants a foot apart is a sufficient mark to make it easy to find the serial individual number of any given plant in the row.

In like manner seed grown in a given year of varieties given numbers in the Accession Book can be designated. Thus Minne-

sota No.25 - '08 flax means seed of that variety grown in 1908. Where the proper name is used the year can follow the name of the variety, Primost - '08 flax, meaning seed of that variety grown in 1908. Or where both the name and the number are written the following form can be observed for a given sample of seed: Primost (Minn. No.25) -'08 flax.

Seed bins, boxes, bags and packages wherever stored or for however temporary a purpose, should be most carefully labeled. The number of the variety of the nursery stock or of the individual plant and the year in which the seed or clonal part was grown are the most essential facts. The grower, the field, series and plat are also important, and in many cases the proper name should also be on the label. Where practical to do so tags should be tacked to wooden receptacles and metal receptacles should have label holders. For bags, wired tags should be provided and the wire should never be used for a tying cord, to be separated from the bag upon opening it, but should be thrust through the cloth, using a separate cord for tying the mouth of the bag, that the tag may never be separated from the bag until the seeds are removed. When the bin, box, bag or other receptacle is emptied the tag should always be removed, lest its presence when other seeds are placed in the receptacle should lead to error.

Picture of wired tags.

A careful plant breeder finds a system of numbering useful in keeping detailed account of the numerous stocks with which he works. In describing a certain kind of plant to the public, however, he needs to use the names of the class or variety with which they are acquainted. The proper names often come to have large significance, as Blue Stem Wheat, or Duchess

Apple, or Swedish Select Oats. Names are of no special advantage as long as the new varieties are in the nursery or in the field variety tests, where numbers best serve the purpose of historical record keeping, and there is advantage in giving names only to new varieties when they gain the honor of being chosen for distribution to growers. This plan avoids confusion arising from too many names.

Proper Names Serve in Final Distribution to Growers.

The breeder and distributors need some uniformity of usage in the way in which proper names and number-names are employed in the breeding and in the distribution of varieties tested for their values in production. The Minnesota Experiment Station distributed some new varieties under numbers, as "Minnesota No. 13" corn; "Minnesota No. 163" wheat; "Minnesota No. 169" wheat; "Minnesota No. 26" oats and "Minnesota No. 105" barley; and one new variety of flax under a proper name, "Primost" flax, known in the breeding record as (Minnesota No. 25). This experience has shown that a number serving as a proper name of a variety is as easily brought into use by growers as is the proper name. On the other hand, it is believed that the name is often to be preferred to a number, using the number incidentally. Then the name first given can be followed by the year in which a given stock of seeds were grown, thus indicating any improvements to that date, or a new number-name and a new proper name may be given. Thus Primost Flax, (Minnesota No.25) as named when distributed in 1905, if further improved, might be distinguished as Primost (Minnesota No.71) (originated from Primost Minnesota No.25) '09, the year showing the date when the seeds were grown.

In draughting room.

A Safeguard Against Unscrupulous Breeders or Dealers.

While new varieties are given to growers under proper names, as Grimm Alfalfa and Primost Flax, it is wise also to give wide publicity to the number of the variety, thus Grimm (Minnesota No.4) alfalfa, Primost (Minnesota No.25) flax, or Primost (Minnesota No.7) flax. This can be done in official correspondence, on shipping tags, and in any bulletins or advertising matter which the originating institution or establishment or the distributors may issue. Growers and dealers in new and highly accredited varieties should use both names and the number-names given by the originating institutions in their records and if desired in their publications. They can also use their own office numbers. Thus a firm of seed merchants can write the name of Primost Flax, "Primost (Minnesota No.25) (O.N.12)", meaning Primost Flax sold by the Minnesota Experiment Station in 1904 and numbered in the Oak Norton Seed Company's Accession Book as Variety No.12. If the Oak Norton Seed Company makes improvements in this variety it can add to the name the year to which its seeds were by it improved, thus ("(O.N.12)-'07").

This plan, together with the technical descriptions such as are mentioned on p. , makes careless or unscrupulous growers or dealers more careful in giving new names and making unwarranted claims for the value of the variety or for the credit of its origin. In some cases plant breeding establishments, knowing minute botanical characteristics of their newly originated varieties, have been able to catch unscrupulous dealers and growers, who, having secured the new variety, soon after its introduction have changed the name and distributed it as something new of their own.

The Accession Book.

The official variety record numbers, kept in the Accession Book, enable the breeder to accumulate performance pedigrees of varieties and to be nearly certain that they will not be applied to the wrong stock of seeds or plants. The actual seeds, cuttings or scions, numbered and preserved with careful descriptions, thus have the exclusive benefit given by the laborious work of breeding and testing for and recording intrinsic values for pedigree purposes. If a sample of Minnesota No. 169 wheat were given another name by a dealer, regardless of the wish of the introducer, he would lose thereby the moral right and opportunity to use its official record of yields and values per acre in the tests where it was compared with all other wheats of its class, in which the records of the Minnesota Station show that it excels. Dealers have frequently recognized the peculiar commercial value to them of the existence of even sub-variation of grains with a performance record made on a public breeding farm, by giving in their catalogues the specific history of excellence as shown in tabulated data which they accredit and use in advertising the actual variety represented. The value of connecting historically the actual seeds or clonal stocks of the variety with the data concerning it in the records of the introducer or breeder who distributed it is coming more and more to be recognized in commercial plant and seed distribution. The breeders of trotting horses and of dairy cows have long recognized the value of tabulated performance records.

These numbers prefixed by the abbreviation of the state, Minn., Wis., Iowa, etc, provide a usable number reference to all

varieties. It is of very great importance that in all official publications the breeder or experiment station use the number along with the proper name till the two are generally associated. The number always traces back through the invoice books, field test books, and nursery records to the exact seed and pedigree or source of the variety; and traces to all recorded facts as to methods used for its improvement. Thus Minnesota No. 169 wheat, or Primost (Minnesota No. 25) flax, can be traced back through the records to the individual mother plant, to the accessioned parental variety and to its source from which each, respectively, was originated; and to all the records as to the methods of breeding a given variety can be assembled.

Number for Each New Stock of the Same Variety.

There is a fatality in the mixing of varieties of seed grains which are similar, and even of mixing varieties quite unlike, and often varieties are changed by natural hybridization or by selection. It is therefore often necessary to record under a separate number each accession of seeds and even of separate invoices of the same well-known variety. Its name may be retained, but the experimenter needs numbers by which he can trace each separate invoice of seed stocks, scions, grafts or tubers, so as to know all available facts concerning them. In case of corn, for example, samples of Boone County White may be received from each of four men. One man may have very carefully bred it especially for yield per acre, another may have been equally careful in breeding it for uniform good appearance of ears; a third may have bred it to ripen earlier fora climate with shorter growing season; while a fourth may have

allowed it to become hybridized with a different variety of corn, each materially changing its character. A number, practically a number-name, for each invoice treats each newly accessioned variety from other establishments or from one's own breeding establishment as if it were entitled to a proper name in the breeder's own work and records.

A variety of wheat which is close-pollinated and, therefore, cannot be mixed except as another variety may be mixed with it mechanically in the bin, having originated from a single mother plant of Blue Stem Wheat, was returned to the Minnesota Experiment Station after an absence of two years, with a mechanical mixture of 5 per cent of Fife Wheat. If each invoice had not been separately designated, the carelessness could not have been traced to its source and the proper person held responsible. In case of varieties of apples and potatoes, each of which are but asexual parts of single plants, they are often mixed and are sold untrue to name. A number attached to each invoice will often aid in tracing and correcting errors, and persons once charged with a mistake will have specific reason to learn to use greater care.

Whether the distribution be free, or for trial, or by sale, the experiment station finds advantages in a simple system of numbering under which the history of every sample distributed can be traced. It is sometimes necessary to know on which field or plat a given sample of seeds or plants grew. The system herein outlined of numbering fields, series, plats, also the varieties and nursery stocks, makes it possible to keep the historical record of inheritance lines complete throughout.

Recognizing Improvement in Varieties.

The most difficult phase of naming varieties is in connection with varieties which are being rapidly improved, even after they are first introduced, especially the open-pollinated varieties, as corn and sugar beets. The improvement at the Minnesota Station of a variety of corn known as St. Paul Yellow Dent (Accession No.13) was begun fifteen years ago. After a few years the improved stock of this variety was distributed as "Minn. No.13". Later an attempt was made to use Minn. No. 172 as the name of a stock resulting from further improvement of this variety. It soon proved that dropping the Minn. No. 13 and giving the new number 172 was a distinct disadvantage, as the reputation associated with the earlier number-name was no longer used to an advantage under the new number-name. As it was apparently necessary for a new reputation to be made by the corn under the new name 172, the use of the old name, Minnesota No.13 was resumed. Had the proper name St. Paul been used, and had the number-name, Minn. No. 13, been used only incidentally, the new number-name could have been advantageously substituted thus, St. Paul (Minnesota No. 172) corn.

The breeder can add the year in which a given sample left his hands, thus, Minn. No. 13 (Minn.Ex.Sta.'03) corn, or Minn.No.13 (Minn.Ex.Sta.'09) corn, meaning that it was sold by the originator with improvements up to 1903, or another stock improved up to 1909.

In like manner it is important that the breeder of each strain of a given variety have his own improvements recognized. Thus, John Moore, of Hardin County, Iowa, and Frank Patton, of DeKalb County, Illinois, may each be breeding Boone County White

Corn. After several years the corn on the two farms will have diverged widely, each farmer having adapted this famous variety to his own region and changed it somewhat to his own ideals. The name written "Moore's Boone County White - '03" or "Patton's Boone County White - '05" would indicate the seeds of this variety bred by Mr. Moore as sold from his crop of 1903, or as improved by Mr. Patton to the year 1905. These names may seem long, but they briefly tell facts and carry whatever of pedigree values the work and reputation of the respective breeders may stand for. Minn. No. 169 wheat, grown at and distributed from the branch station at Crookston in 1908 could be labeled Minn. No. 169 (Crookston '08) wheat. A variety originated at the Crookston station and seed of 1908 distributed could be recorded as Minn. Crookston No. 387 - '08, wheat. In this way experiment stations, branch stations, firms and individuals may designate their introduction of new strains or varieties.

A central agency as the Bureau of Plant Industry of the U. S. Department of Agriculture for recording names and abbreviations might serve useful purposes. Its advice in devising schemes of naming to be used in advertising would be useful to the breeder who desires to properly label and advertise his seeds and plants. There is force to the suggestion that the U. S. Department of Agriculture should form a register of all varieties, and should give a U. S. number-name to each and every definite variety of each species of plants.

EXAMPLE OF HOW NOTES ARE USED.

In the field trials a record is kept of each variety in the "Field Year Book", showing the plat on which it grew and its name and accession number.

These records serve as connecting links in the records of the varieties back to their parentage. Thus, Minnesota No. 659 wheat, in variety field tests 1901, 1902 and 1903, traces back to nursery centgener 1301 - '99, which, in turn, as a breeding stock under improvement by selection since 1896, was in the nursery as "N.S.No.4 - '96", from mother plant 2670, of the crop of 1896. In 1897 its centgener plat number was 1701. In 1898 it was in a centgener test plat under Cent. No. 1701, and in 1899 under Cent. No. 1301, mentioned above, from which the seeds went to the variety test plat in 1900.

Having made a high efficiency nursery record it was placed in a smallfield plat in 1900 under the variety number-name of "Minnesota No. 659". The plats being very small the yields of this and other varieties were not recorded. Under this number it was in variety field plat tests in Plat 5, Series V, Field "A" in 1901; in Plat 19, Series II, Field "C" in 1902; and in Plat 21, Series IX, Field "T" in 1903. After these three field trials its average yield was compared with standard varieties and if it has been superior to all others it would have been increased to several hundreds or thousands of bushels and distributed to the farmers of the State.

Fig.21. Section of case with half bushel iron seed grain storage boxes.

Fig. 20. A storage room for nursery stocks. The storage boxes 12 x 7 x 10½ inches high described on page are arranged in order of years and classes of grain, and when necessary can be easily reclassified as loose leaves in accounts and records. These were made of pasteboard covered with glazed paper, but tin should in all cases be used.

Places for Storing Seeds.

The storage of seeds to prevent injury by vermin and insects and to preserve their full germinating power, under some system where mixing will be avoided, where names may be kept without error, and where each can easily be found, is a matter of more importance than would at first appear. The following are found useful.

1. Bins should be provided in a room or seed house with mouse-proof walls and kept as free from vermin as possible. These bins may be of such sizes as may best accommodate the desired amount of grains.

2. For quantities of a half bushel or less galvanized or tinned iron boxes, 9-1/2 inches high and 12 inches in diameter and fitted with a loose iron cover with one inch flange, as shown in Figure , serve their purpose well. On the sides of these boxes are fastened tin label holders which receive the label cards. They may be closely packed in cases with shelves a foot wide and a foot apart. These boxes, at 30 to 50 cents each, are less expensive and far more satisfactory than bags, which are often injured by rodents, resulting in the destruction of the bags, loss of grain, and mixing of varieties of seeds. Round iron boxes cost less and keep their form better than square boxes, though they require somewhat more shelf room.

3. Covered tin boxes, 12 x 7 inches and 10-1/2 inches deep, serve well as storage cases for the seeds of individual plants, selected spikes or heads, etc., also for small lots of "bulk seed", each placed in such an envelope seed packet as is shown

Fig. A planting envelope (3 x 5 inches) showing the method of labeling and storing the seeds counted out and ready for planting. The Nursery Year Book is compiled from these and they serve as a valuable reference in checking up the location, identity, etc., of the planted stocks.

in Fig. . These boxes are also arranged on shelves 12 inches wide and 12 inches high, permitting of easy reclassification of the boxes and of their contents annually if needed. Index labels are pasted on the outer ends of these boxes showing lists of enclosed seed packets, thus facilitating the finding of desired seed stocks.

4. Bags of cloth from the two-bushel grain bag to the small muslin bag are useful for handling and shipping seeds. The smaller sizes, by placing the bags inside the iron and tin seed boxes, are successfully used in storing small samples of seeds.

5. Seed packets for small quantities of bulk seeds and for the seeds of the unthreshed heads of individual plants, and for storing seeds sorted out to plant in the nursery, are very necessary. Two kinds of envelopes have been found to answer the requirements and to fit into the system of boxes above described.

A. Envelopes of tough linen paper, 6 x 9 inches, with the flap at the end, and glued with extra quality glue. Special care is used in gluing so that they may serve as safe seed packets. (See Fig.)
Blank forms printed on these bags serve in expediting the recording of notes when harvesting individual plants, or spikes, as shown in Fig. .

B. Seed packets of manila paper, 2 x 4 inches, in which to place seeds counted out to plant in small nursery plats. (See Fig.)

Fig. .1.A harvesting envelope (6 x 9-1/2 inches).2.As this envelope is often used for a bag it is made of tough Manila paper and sealed with special glue to prevent bursting open with dampness, the dotted lines show the overlapping of glued edges.

Fig. The Individual Plant Harvesting Envelope, showing scheme of notes on individual plants. Such notes are taken of plants chosen from foundation beds or foundation stocks in field preparatory to selecting parent plants to subject to centgener test.

Systems of Records.

Comprehensive yet simple, practical systems of records and of storing, foundation varieties, of nursery stocks, of new varieties and of varieties distributed to growers are thus of great importance. Into the Accession Books go the records of all varieties, whether received from outside sources or originated in the breeding nursery. Into the Variety Year Books go records of all tests in variety field plats. Into the Nursery Year Books go records of all nursery planting and tests. Thus these three series of books each year are the annual keys to all other notes.

The Variety Year Books and Nursery Year Books are supplemented by loose leaf systems, both for record and for ledgerizing yield, quality, etc., that such comparisons may be made as may be needed. These sheets ledgerized up to date, will at all times show the relative values of all nursery stocks, of all stocks under test in field plats, of all tests of leading varieties at a group of experiment stations, and of all records reported by growers of pedigreed seeds and by growers in general.

Nursery Year Book.

The data relative to the planting, harvesting, yields, etc., in the nursery where are planted the very small plats and the individual plants, are recorded in a book which for convenience is called the Nursery Year Book. A new book may be used for each year sufficiently large, 200 to 500 pages, to contain this data for all the crops operated in the field crop nursery of a given firm or institution or division of an institution. Thus we have the 1907

N. Y. B.; 1908 N. Y. B., etc. These books also serve as a means of tracing the ancestry or the pedigree of a given stock back to its first introduction into the nursery and, hence, back to the Accession Book. In the first column is placed the nursery or centgener number of the current year. The double page tabular arrangement is shown in Table . (Please insert copy from 2 pages of wheat, N.T.B.) In the third column is the nursery or centgener number of the previous year, from which the particular stock generated. The nursery stock number is then placed in column 2, the Minnesota number in column 4, and the name of the parental stocks in column 5. In columns 6 to 19 inclusive are placed records which apply immediately to the centgener plat or give its performance record.

These forms are made full so as to serve both in general centgener selection and in theoretical experiments. It is not expected that all the columns will be used each year in any given effort at variety improvement nor in any given research in breeding. And in many cases where the breeder knows definitely what he wants, only such notes as are needed are provided for and only part of the box heads need be centered.

Planting Envelopes.

Manila envelopes 3 x 5 inches have been found convenient to use in planting seeds of the cereal grains, grasses, clovers, etc. In these are placed a given number of the selected seeds to be planted in the various nursery beds or rows. Notes used on these envelopes are shown in Figure . The envelopes containing the seeds to be carried to the field are arranged in that numerical order in which it is designed to plant the centgener plats

in the nursery.

Harvesting Envelopes.-- Tough linen envelopes 6 x 9 inches, as noted on page___ carefully glued with especially chosen glue serve as seed bags and are very useful both as receptacles for seeds from nursery plats and as means of filing and tabulating the notes of the respective plats. Figure ___ shows the blank form used on some of these envelopes which are designed to receive the notes while the harvesting, threshing and the making of laboratory tests of these seeds and centgener plats are being carried out. The original data thus placed on the package containing the seeds is transcribed directly to the respective horizontal lines in the Nursery Year Book, as in Figure ___.

These envelopes can be used both for the receptacles of the seeds of selected mother plants from foundation beds and to receive the notes concerning such plants while laboratory tests are being made to continue the selection from those saved when harvested.

When the series of plants is large and the selection of a goodly number of the best is based on small differences in a number of characters, it often is wise to copy them on blank forms or even in the Nursery Year Book.

It has been suggested that the notes be used as a score card; that score card "weight" be given to each characteristic, and that the record of any given plant be multiplied by this weight, giving a coefficient to be used to formally reduce the general values of each parent to a comparable basis expressed by a single number or single numerical statement. But only in rare cases is this refinement of statistical methods necessary. By inspecting the columns of figures on the separate envelopes, the breeder can

usually choose the best without trouble. The breeder soon learns to make a "weighted" comparison giving the larger "weight" to yield, or to such special character as may be a special object sought in the breeding.

<u>Covering Centgener Bundles</u>.

In the breeding of grains, grasses, clovers, etc, it is often necessary to protect the centgener bundles of seeds from swallows and other birds. The areas used become quite too large to cover the whole with inch-mesh wire netting. But it is quite practical to thus cover small areas into which centgener bundles can be collected while they are being dried, preparatory to threshing. This can be accomplished by constructing movable tents 16 x 16 feet square as six feet high with sides and top covered by the inch-mesh wire neating, or by covering a larger area with the wire netting supported by posts placed in the ground. In yet other cases large buildings are available into which the centgener bundles can be stored to dry them for threshing.

In any event threshing those centgener bundles where exact yields are sought should not be long delayed, because of so many contingencies which may cause the loss of a portion of the seeds. In harvesting centgener plats of such crops as wheat, oats, etc, paper bags may be used to cover the head of the bundle as shown in Figures ___, ___, ___, ___. Pieces of muslin 18 x 24 inches wrapped about the head of the bundle and pinned on also serve the same purpose as shown in Figure ____.

Fig.25. Placing heavy paper covers on centgener bundles, to protect the grain from birds and from the weather. (Burnett)

Fig.26. Tying wired tag about the paper centgener cover; both to fasten the bag on the bundle and to place the nursery number on the tag. (Burnett)

Fig.27. Centgener bundles shocked beside the field so that the land may be plowed. The bundles are tied to a wire stretched from guy stakes across taller stakes as shown. (Burnett)

Norton's Thresher.

In Figs___, ___, and ___ is shown a machine for thrashing the grain of mother plants, and of centgener plats of the small cereal grains, beans, millets, and other plants. The cylinder is covered with medium weight rubber soling, and the diaphragm or concave is made of the same material. The heads of grain separated from the straw, are fed in on top of the cylinder which is alternately turned slightly forward and backward, tearing or rubbing the berries out of the chaff. The cylinder is then revolved two or three times in each direction, cleaning the machine and dropping the grain and chaff upon the slanting blast board of tin below. An electric Ban, set at that distance which gives a blast of the desired speed, will force the chaff back over the board and allow the grain to run forward into the receptacle, thus separating the grain from the chaff. A pan can be placed behind the blast board, to receive the chaff, which should be emptied after threshing each mother plat and each centgener plat, thus to make it possible to secure any grains accidentally blown over.

Fig.28. Front view of Norton Thrasher. (Burnett)

Fig. 29. Rear view of Norton Thresher.

Fig. 30. Norton Thrasher in operation; as improved with separating board and blower by L. C. Burnett of Iowa Experiment Station.

Fig. Outfit for Threshing Centgener Plats of Grains.

Minnesota Centgener Thresher.

The thresher shown in Figs. ___, ___, ___ designed by the author, assisted by William Boss and others, consists of an ordinary 24-inch or 26-inch thresher cylinder and concave. The frame of the machine is so constructed that the seeds have no place to lodge, both seeds and chaff falling into the metallic tub beneath. A table covered with zinc enables one operator to untie the bundles and collect all shattered seeds. The second operator feeds the bundle and the loose seeds collected in a tin pan into the machine. A third operator runs the chaff and wheat through a fanning mill to separate out the neat grain. A fourth operator weighs the seeds and places them in a bag.

Centgener Ledger Sheets.

For convenience in comparing the respective values of individual plants, of centgeners, and of other nursery stocks, a system of so-called ledger sheets has been found convenient, and also useful for preserving the history of the plants and nursery stocks; and for some lines of research work. The names of these sheets and their purpose are as follows:

Introductory Sheet for Selected Stock. A complete record of the history and conditions under which the particular stock was introduced into the nursery----Minn.Form 101. (Fig.___)

Notes on Mother Plants.--In selecting plants for mothers of centgener row or plat tests, it is sometimes desirable, especially in theoretical experiments, to record such characteristics as will aid in further selecting those roughly chosen at first in the field or in especially planted foundation bed and as may be needed

as a part of the pedigree history of any resulting valuable strain. The box headings in Fig.31, outlining notes part or all of which may be recorded for wheat plants chosen for mothers of centgener drills, centgener hill-rows or centgener hill-plats, illustrate the manner of recording these notes. These headings may be used in the Nursery Year Book or in other bound books, or, better, on loose leaves, ordinary letter size, (8-1/2 x 11 inches or 8 x 10-1/2). If the plants often represented only by a single head, ear, fruit or cion be chosen from a field or a foundation bed planted for the purpose of securing mother plants, they can be numbered 1, 2, 3, etc., in the first column. If they are chosen from a nursery centgener, the actual nursery numbers may be used, or better a series of consecutive numbers within the numbers belonging to the centgener series from which they were taken. Thus in a centgener the numbers of which begin at 901, the seeds representing five chosen mother plants, respectively, might be numbered 921, 922, 923, 924, and 925. In few cases will it be wise to take notes of the mother plant on more than the few most essential lines; such as yield of grain and grade of grain, in the case of wheat. In case of such plants as apples, or potatoes however, fuller notes of the mother plants should be recorded. If the breeder is seeking to correct or especially improve any one specific character, that character should be carefully noted and recorded. If, however, many notes are recorded, as indicated in Fig. 31, the breeder will become more acute in his observation; and for students or beginners working under an experienced breeder to learn the business, much can be gained by a large amount of this detailed record making. It drills the breeder to critical observation and prepares him to deal with the less easily

observed characters. On the other hand persons inclined merely to record details, to write history, should be schooled in broad observation, in finding the one rare individual in ten thousand. The art of seeing new values, and tendencies must be taught as well as the formal recording of facts. And there is room both for high artistic skill and for rare ability to attend to making and interpreting detailed records in choosing mother plants to enter the clonal or seminal centgener tests.

Form 7. Nursery foundation bed sheet on which are recorded the notes concerning each foundation bed and each plant chosen to be a mother of a centgener. Notes marked with a star in the boxhead are to be taken in the field. (8-1/2 x 11 inches).

<u>Annual Centgener Notes</u>.-- Many notes on the centgener nursery plats of annual, biennial and perennial plants, are recorded each year directly into the Nursery Year Book as they are taken in the field, (Fig.___). The headings on the pages used for this purpose are nearly the same as those in the Summary Sheet for Centgener Notes, (Fig.___), to which they may be transferred after carrying out any needed calculations. The annual centgener notes thus recorded in the field are the original records and are best recorded in the Nursery Year Book, thus avoiding error in copying. The books are easily handled in the field. In Fig.___ are shown box headings for notes on nursery centgener plats of wheat in the Nursery Year Book for 1907, showing the centgener number in 1906 also.

Fig.32. Crossing flax in the centgener plats. The paper covers and appended tags indicate that some of the work has been accomplished.

Centgener Summary Sheets. - The data from the Nursery Year Book and from the harvesting envelopes pertaining to the respective centgeners of a given stock are assembled upon the Centgener Summary Sheet. There the averages are made to get a measure of the stock under several years' conditions. See Fig.___

<u>Centgener Grand Summary Sheets</u> -- This sheet is used for the recording of the averages obtained upon the Centgener Summary Sheets Fig.___. Here are assembled the averages for the three or more years' records of the respective stocks, from which the very best may thus be selected to be increased and carried into the field tests.

Caution Against Too Many Notes.

The plan here followed is to give the scheme of notes in detail, in extenso. For example, on many of the tabulated blank forms on the pages near this note, and also under the treatment of the respective crops in the last part of the bulletin, are numerous box headings, some of which are useful when stressing the breeding for one set of characters, others for other characters, and others to serve in keeping accurate record of the lineage of the several stocks. But the breeder must take short-cuts. Only those blank headings should be filled which are absolutely necessary. These forms should usually be used merely in a suggestive way, as aids in devising blank forms to fit the ideas and needs of the breeder.

<u>Introductory Sheet for Hybrids and Crosses</u>.--As the introductory sheet for selected stock is used for beginning the historical record for the selected nursery stocks, so the introductory sheet for hybrids and crosses is used for an historical record of the parents used and all other similar data concerning crosses and hybrids. Fig.___ shows how such a loose sheet, or a leaf in a book of printed forms may be arranged.

Notes on Cross-Bred Plants.-- Where it is desired to keep records of individual plants of the first generation of hybrids, forms may be devised, of which Fig.___ is an example. Upon this sheet are recorded the plant notes upon the individual hybrid or cross-bred plants of the first generation from the seed. Provision is made for records of the class, type, accession number, nursery stock number and other facts which should be recorded to make complete the pedigree history. This kind of blank form will not in all cases be used, and the hybrid will be grown for two or more years before mother plants are chosen, when the form given in Fig.___ can be used as the first of the loose sheet records of the nursery stock number arising from a given mother plant, and the forms given in Figs. 33 and 34 can be used on which to record and compare the qualities of the respective centgeners.

HYBRIDIZING, ITS FUNCTIONS; METHODS.

The object of hybridizing is so to mix the heritages of two or more parental types that the best unit characters of each may be recombined in an occasional individual in such a way as to give it peculiar power to transmit to its offspring especial value in a desired line. The cross-pollenating is easily and quickly done. The difficult, laborious, time-consuming and expensive work is that of growing large numbers of the hybrid progeny, and of so selecting superior individuals and testing their breeding values that those may be chosen in which are recombined the qualities desired from each parent. Hybridizers who do not have the facilities, the time and the patience to seek the individual of rare power from among the mass of individuals springing from a new hybrid, rarely accomplish anything. There are not many artificially made hybrid varieties of plants in commercial use. The main reason is that hybridizers, not recognizing the law that "there is only one rare individual in thousands of individuals of a variety and only one of rare breeding value in very many thousands", have dealt with relatively small numbers.

It is not usual that the average of all the individuals of the hybrid of any near or remote unselected generation is an improvement over the parent kinds. The new hybrid as a whole is often much less desirable than the parent stocks. There are not many valuable mules in nature. The value of the hybrid usually rests in the fact that it contains an occasional individual with increased breeding value as compared with the breeding values of the best ones in the parent varieties from which useful new varieties can be made.

Among the hybrids there may be greater divergence of the individuals; more poor, fewer medium and very few good or excellent ones than in either parental stock. But among the very good individuals there is sometimes one which is of greater value as the progenitor of a new race than any individual to be found in the parent kinds. Since new varieties and new breeds can be based on only one, or on a few, parent individuals of rare merit, the breeder is concerned principally with seeking the rare individuals and the hybridizer is concerned with creating the rare individual of greatest genetic excellence. To obtain such individuals in the work of selection alone without outcrossing, the breeder may save but one or two of every 1,000 or even of every 10,000 plants. In hybridizing, whereby a greater divergence is secured, the breeder may need 10,000 or 100,000 plants in the search for the one or more "best" but once this "best one" is secured, it may possess greater breeding efficiency and higher pre-potent value than those from stocks secured under selection alone. It is more than reasonable to hope that much more pronounced results may be secured by hybridizing and selecting upon a large scale than by selection only within existing varieties.

In case of discernable Mendelian characters the recombining may be done in such a formal way that the numbers required are much reduced. Even here, however, since the recombined Mendelian characters must be joined with characters which are not discernable in a network of descent which on the whole gives increased value to the new variety, to secure the most valuable mother plant, or group of interbreeding mother plant large numbers must be used.

Thus it may be possible by hybridizing to adapt alfalfa to lands somewhat alkaline; to produce flax which will better thrive

in the presence of flax wilt, red clover more hardy from the north; alfalfa better adapted to the cool moist climate of New York and surrounding states; apples which will thrive in the warm climate of the Gulf States, oranges which are hardy hundreds of miles north of the present orange zone, wheat and other cereal and forage crops which will better endure the drouth of the semi-arid belt; potatoes and corn which will yield increased amounts of starch and alcohol per acre; cotton which will thrive in regions where that crop does not now succeed; or grapes at once resistent to phylloxera and even more prolific in value per acre than were the original varieties not resistent to phylloxera.

But even more important is the substantial increased yields of value per plant and per acre which can surely be thus secured in case of those staple crops which are already locally placed and which yield the bulk of our several billion dollars' worth of field, horticultural, garden and forest products. There is inspiration in the fact that our living forces are not fixed and that each improvement in hereditary power along a given line becomes a basis for another advance. Research may find shorter cuts, may displace the plan of scientifically crossing and selecting very large numbers to secure very important results, but without shorter cuts the path is neither difficult nor expensive as compared with the goal to be sought in added hundreds of millions worth of crops annually.

Since creating new varieties of hybrid wheat, or oats, or apples is a process no longer than bringing up a family of boys and girls, it should not be considered either tedious nor long. Nor are the details of the work without its very great pleasures, nor do

the resulting values to one's fellow man fail to satisfy greatly him who plants and plods and waits.

<u>Choice of Foundation Stocks in Hybridizing</u>.-- As a rule, it is wise in making hybrids to choose for foundation stocks those kinds which most nearly suit the requirements. However, the wilder, less nearly adapted forms often have a place as one of the parents to bring in one or more desired characters, especially when the blood of more than two kinds is compounded. The important consideration is that the several parent varieties contain characters which when properly compounded and recombined will give to the new variety the desired general variety characteristics, or that possibly new values may be created, so as to have the largest possible net value per plant, and per acre in field crops--or per head and per herd in animals. In some cases a wild native plant can be introduced as one of several parent forms, with a view to giving hardiness and adaptability to the soil, climate and other local conditions, or to giving some new quality of economic or artistic value. Beginners at hybrid breeding, however, should, as a rule, make simple compounds of foundation stocks already valuable, leaving the more radical and complicated hybridizing to those whose experience and financial ability warrant the undertaking of difficult and long-time projects.

As a matter of general experience in securing important results the history of breeding plants would indicate that crosses between not widely differing superior cultivated varieties and between long separated stocks of the same general variety, have more frequently given improved forms than hybrids between radically different varieties. Mendelian principles promise to lead to a larger

proportion of successes with hybrids in case of which the characters are sufficiently distinct as to be treated as discernable Mendelian units, and thus formally recombined. And there is ample opportunity to make improvements in crosses and hybrids of all degrees of narrow and wide breeding from the mixing of two nearly related strains of the same variety up to the recombination of characters in species which differ so radically as to be barely able to produce fertile hybrid progeny.

As experience accumulates, it will be found that certain crosses produce very few, if any, individuals of value, while other combinations of blood produce a relatively larger number which may be used as parents of useful varieties. Thus it is known that Persian x Oriental peach hybrids contain a comparatively larger number of plants capable of being multiplied into superior clonal varieties for the humid Atlantic States than hybrids in which certain other blood lines are brought together. Burbank reports many useful plants among the hybrids from two classes of plums. Hybridizers of plants and animals should record and publish failures as well as successes, so that other breeders may choose those classes of crosses most likely to be successful. In other cases the very valuable new strains may occur only infrequently but be relatively of high value. The number of valuable new strains may be of far less concern than the degree of the rare mutation. Whenever such facts are available, they are helpful in deciding the crosses to make. The creative breeder who makes hybrids should choose his lines of effort with ~~great~~ care, so that the large expense and the long time required to test in the plant breeding nursery, in field test plats, and in commercial use, may result in the largest poss-

ible outcome. The elimination of weak hybrids from among large numbers may be carried out rapidly and cheaply during the first few years, preserving only the very promising individuals for the closer and expensive selection during succeeding hybrid generations.

Methods of reproduction.--- The several methods of pollination and of asexual reproduction must be considered in the production of hybrids. In case of the apple, the new variety, whether from the seed of a self-pollinated flower or from a seed resulting from natural or artificial cross pollination, is the product of a single seed. This seed produces a tree which, proving hardy and a prolific bearer of superior fruit, is used as the basis of a new variety. The breeder takes scions and buds from this tree and by grafting produces other trees. These are not sexually new trees; they are asexual parts of the parent tree. Each came from a clon, a segment of the original tree, and as these clonal trees are multiplied by cuttings from the original tree or from the clonal progeny, a clonal variety is produced. In case of clonal varieties, as apples and potatoes, the selection is concerned with the breeding - power of the original seed, because all the clonal progeny have the hereditary characteristics and power of that seed. There is such slight bud variation that it can usually be ignored, at least at first, the effort being directed toward the recording and measurement of the relative values of the heredity in the respective seedling apple trees or seedling potato plants used as parents of the clonal varieties. In rare cases, however, bud variations may be followed up with profit. And bud varieties with mutating values along such vital lines as yield, resistance to disease and hardiness may be very important.

Fig.33. Instruments used in cross-pollinating field crops.
Dissecting scissors with sharp narrow points.
Tapering and sharp pointed tweezers.
A good hand magnification lens with chain or string to fasten to shirt or vest.
Small tags for proper labeling.
Tissue paper and string to wrap the treated head, spike or flower

Fig. . Oliver's Outfit.

(Get cut from Oliver's bulletin)

Fig. . Oliver washing the pollen off the pistil of an alfalfa floret.

(Get cut from Oliver's bulletin)

<u>In Self-Pollinated Species</u>, as barley and wheat, the new variety is usually as clearly based on a single seed as in case of apples and potatoes. Here, however, the reproduction instead of by buds, cuttings or other asexual clons, is sexual, by seeds; but both sexes are in the same floret, and the lineage on both sides traces back fo the single-parent seed. By making many hybrids, growing many individuals of several generations; following out both formal Mendelian recombinations, and artistic and statistical centgener selection for the best possible combination of nondiscernible as well as discernible characters, thus seeking the occasional plant of hybrid origin with highest breeding efficiency, or mutant, that mother plant is secured which has the qualities of being parent of a new variety.

While the hidden processes of the generative cell are being unravelled, we can not hope to know of all the intricacies; and it is probable that these self-pollenated variety parents may in some cases be found in an early generation, but more frequently in those several generations removed from the first cross. Where definite Mendelian characters are so recombined as to constitute in the new variety all the leading characters vital to yield per acre, quality and other qualities which go to make up the economic unit it may be possible to work in a rather formal way with relative small numbers. But where these major characters and many minor characters are woven together differently in the many individuals of the hybrid the quest for that one which is best fitted to serve as a variety mother must be sought from among large numbers. Here the selection by inspection of heads from many promising plants and the testing of these first crudely to eliminate all the poorer ones,

and then with much care to discard all but the few very best must be such as will result in finding plants with peculiar power to produce young with high average efficiency. One can only guess whether these rare genetic plants occur more frequently in second, third, fourth, fifth or later generations. Experience and theory would indicate that the selection be broad in each generation. The reduction to a few hybrid seeds and their first generation hybrid plants; the selection from only a few from among the second generation plants, and again in the fourth, narrows down the basis for recombination and selection. Even the choice of stocks to be hybridized should be done broadly, that is a number of xarieties and numerous plants within each variety should be used. It is to be presumed that the plant of the earlier generations of hybrids will be more likely to produce a variable lot of progeny than will a plant several generations removed from the first generation hybrid. However, variation among the progeny of the plant of a self-pollinated variety from a single seed is relatively small as compared with the variations among the widely bred progeny of open-pollenated species. It is not here usually troublesome to secure stocks from single mother plants which are uniform. Nearly the whole quest is for yield and other characters the sum of which is expressed in yield of value per plant or per acre.

In Open-Pollenated Species, as corn and hemp, the new variety is based on an interbreeding group of plants, and it is not usually practicable in any one generation to reduce the parentage to a single parent plant artificially self-pollenated. At least it is believed that such close breeding would be disastrous in case of nearly all species accustomed to open fertilization. Here the constant Mendelian recombining of characters sufficiently different to be discerned and of characters with differences too minute to be formally followed in Mendelian recombination, results in a greatly varying network of descent. The new strain or variety is brought toward uniformity only with repeated selection to a purpose, as of large yield, and to a form, as character of plant as observed, measured or otherwise tested.

And here as in clonal or self-pollinated mother plants, the paramount work is in measuring the variety producing values of the blood of a large number of parent seeds. The long, tedious nursery, field, laboratory and commercial testing are efforts to compare the projected breeding efficiency of the respective seeds which produce the plants chosen as parents of nursery centgener plats. In hybrids of self-pollinated species, as wheat, excepting in the selection of Mendelian characters beginning with the second generation it is the custom to wait at least till the third generation before selecting out individual mother plants with a view to testing the power of each to project high efficiency into a new strain which might be based on its blood. But where large numbers are used selection can begin in the second generation.

Methods of Handling Flowers.-- The emasculation of many of the flowers and the hand application of foreign pollen is in

most cases a simple matter. In case of beans and peas there is greater difficulty and in case of many small and delicate flowers the work is tedious and in some cases wellnigh impossible. In some species it is more practical to plant two kinds near together and provide for cross pollination by the wind or by insects. Under the chapters on the several species, on following pages, detailed instructions are given illustrating some of the difficulties and methods. As a rule, those flowers which are to be cross pollinated are first separated, as by careful removal of their neighbors or by covering them to prevent the entrance of pollen. The second operation in case of perfect flowers is to remove their anthers to prevent self-pollination, marking so as to record the two parent plants, parent varieties, the date, the initials of the operator and other needed facts. These two operations must be completed some hours or days before the stigmas are receptive to pollen. The third operation is to secure the foreign pollen, which is usually done in the same or a nearby field just before using it. In some cases the pollen may be brought long distances and be kept dry and alive for some days. The fourth operation is to apply the pollen to the receptive stigmas and when necessary to again close or cover the flowers to prevent the entrance of other pollen. When this is done, any seeds which may result are allowed to ripen and are then carefully harvested, labelled and preserved. See Figures__________ Bulletin ___ of the Bureau of Plant Industry, U. S. Department of Agriculture gives suggestion as to methods of cross-pollinating of numerous species.

Starting Hybrid Plants.-- A group of plants from a lot of hybrid seeds, whether from the flowers and pollen of two plants, or

from the flowers and pollen of numerous plants of the same two varieties or species, are not, strictly speaking, a variety. They are a group of cross-bred or hybrid individuals, sometimes capable of being thrown together into groups which will ~~multiply~~ interbreed without great variation; but usually multiply producing self-bred or interbred progeny which varies too greatly to be worth a varietal name.

In case of self pollinated species, as wheat and barley, new hybrid varieties are made from such single parent plants as are proven by trial in the nursery and field to have strong heredity along desired lines. And the method followed is to grow the hybrid for two to five years, making general selections meantime, and then plant large numbers of seeds of the best types and from among these secure promising plants, the seeds of which are to be tested in the centgener test plats as to the efficiency of the parent plants as progenitors of varieties. (See chapters on Wheat, Barley, Oats, etc.)

In case of new hybrids of such open-pollinated species as corn, varieties are made not from single hybrid plants, but from an interbreeding group of parent plants which possess both high-breeding power and great adaptability to blend in a "useful flux of blood", or "an efficient network of descent", of high average value per plant or per acre.

In case of such species as tobacco, which are open-pollinated, yet in which self-pollinated seeds are as good or better than those produced by crossing, the new variety may best be made from the self-pollenated seeds of a single mother plant.

Each species at this point in the breeding requires some handling peculiar to its own nature. Especially are the requirements different for open and close pollinated species; and species subject to clonal reproduction are handled differently from those reproduced by seeds. The laws deduced by Mendel and those who are following up his method of research are already helpful in laying out the plans to be adopted with each species. But much of the work of devising and proving methods is being wrought out by the men who are breeding directly for increased values. These newer facts necessitate that the breeder of each species make specific plans for the treatment of his hybrids during their first years. It is a matter of very great wisdom to widely consult others who may criticise one's plans so as to point out the impractical features and to give helpful suggestions. Schools of methods in breeding are being organized by our agricultural colleges, and those who wish to follow plant breeding as a business, or even engage in amateur plant breeding, should attend courses of study where both theory and practice work are given. And since new facts are being constantly discovered the hybridizer needs to be in constant touch with those who are investigating heredity and breeding.

TESTING VARIETIES.

Those State experiment stations which have most thoroughly organized the testing of varieties in connection with breeding by systematic selection, and by hybridizing followed by selection, are fully convinced of the economic value of a well-equipped plant breeding establishment, with branch testing farms, in each large agricultural region, for testing varieties of field, horticultural and garden crops, and even of forest crops. Proper notes on im-

proved forms of plants can be secured only by proper testing of varieties under conditions where their values may be compared, and comparable to the conditions under which growers wish to plant them. As before mentioned, the first requisite is an abundance of land on which plats uniform in character may be laid out and used continuously.

The Sizes of Plats for Testing Mother Plants and Varieties is not nearly so important as the uniformity of the soil. In fact by the use of short rows and other forms of small long shaped plats with duplicate and triplicate plats, much can be done to correct the irregularities of soil, and thus reduce the conditions of the soil to a nearly uniform basis for all varieties, thus securing a nearly expression of the heredity values of the seeds or clons planted on the duplicated plats from the respective parent plants.

Thus the five foot drill rows from the single heads of wheat, oats or barley, representing many mother plants from which the heads in the ripened field, serves to make a crude centgener test with very slight cost of a large number of promising mother plants. By adding a little more expense and gaining more of accuracy the seeds from the single spike or panicle can be planted in the seventeen foot hill row. The seventeen foot drill row serves to test the seeds of mother plants of these crops chosen from the hill planted foundation bed or secured with care from the field, as in the Mendelian selection of hybrids. The rectangular hill plat is a more accurate form of plat for testing the seeds of the mother plant. Especially in the early generations of hybrids and in theoretical experiments is the hill plat both inexpensive and most efficient form of plat for centgener tests, and centgener hill planting

devices are very useful.

Once the stock of seeds from a single parent plant, or from a group of parent plants, has become bulk seed to be planted in the ordinary field way, plats of larger size may be used. Many of these tests are preliminary. They are not to serve as records for publication, but merely to serve in the elimination of the many so as to secure the few very best. Therefore plats of any convenient size may be used. Professor C. A. Zavitz has most excellent results by using very small plats, so small that all the work is done by hand. This makes it possible to so train a few workmen that a large plant breeding establishment can be carried forward with great accuracy. Most of these plats range from one one-hundredth part of an acre down to one four-hundredth part of an acre. These smaller plats greatly economize land, labor and storage room, as well as increase the accuracy of the work. With a given expenditure they allow of more duplication, and the writer is converted to the belief that the small plats should be much more widely used with cereal, forage, vegetable and other smaller plants. In case of corn, cotton, potato, fruit trees, forest trees and other larger plants or plants among which intercultural horse tillage is used the sizes of the plats must be adapted to the conditions required by the crop.

Preparing the seed bed.-- The land for variety field tests should be prepared with nearly as much care as land for the plant breeding nursery. Since the different varieties somewhat unevenly affect the fertility of the soil, it is necessary to rotate the variety tests of the species to be tested with crops which prepare the land for the species under test. Thus variety tests of spring

Mr. Williams: Place "X" at top of tube; "T" on middle of tube, and "B" on box at bottom of tube.

Fig.86. A seed grader. By the force of the wind blast the light seeds are forced upward through the vertical tube (T) nearly four feet. The heavier seeds fall into the box below (B) while the lighter grains are blown out at the top of the tube (X).

wheat in Minnesota may be grown in alternate years with variety tests of corn, planted at right angles to the direction in which the plats of wheat were laid out. In this case, to avoid growing the wheat continuously on the same side of the furrow slice, and the corn continuously on the other side, the wheat stubble should be twice plowed before planting the corn. If a first shallow plowing is done immediately after harvesting the plats of wheat stubble to prevent weeds ripening, and the second deeper plowing is done later in the fall or the next spring; and if the corn is kept clean of weeds, the weeds will be gradually diminished. Many devices similar to this are necessary, and a thorough knowledge of farm management is one of the most important requirements on the part of the successful breeder of field and other crops, that the land for the field plats as well as that for the breeding nursery plats may be in good condition each year for the respective crops.

An experiment farm in which variety testing is one of the leading lines must be well organized so that suitable land may be available for the required number of series of plats for the several classes of varieties to be tested each year. It is important that there be series suitable in size so that all varieties of each class may be on plats of soil similar in yielding power, that their yields may be compared and tabulated from year to year. This requirement makes farm management on an experiment farm an important problem, requiring foresight as well as skill. In many cases, especially where the rainfall is light, alternating a year of bare fallow with a year of plat tests is almost necessary. It adds much security against the occasional year when the drouth is so severe that the plat tests are a failure. By means of a summer fallow, moisture is

accumulated one year for the use of the crops the next year. In some cases, where the land is poor, a uniform planting of some leguminous crop like cowpeas or field peas may be grown the alternate year and plowed under when green, thus to make the soil more productive, as well as to bring it to greater uniformity of condition. In many cases it will be found that a two-course rotation will not provide good conditions for a given crop. Where sufficient land is available it is well to divide it into several series so as to accommodate a three, four, five, or even longer rotation. Then when a given crop comes in the rotation the variety test plats of that crop can be planted. Land used for variety tests should be kept free from weeds, because weeds are rarely evenly distributed and they injure one plat more than another.

Field Variety Year Book.-- A book called the Field Variety Year Book, one for each year on an experiment farm, serves to record the planting notes and other notes of variety test plats. The tabular forms under the respective crops on pages ____________ show the headings used in recording the planting notes, numbers, names, etc., also the notes of yields, disease resistence, for the respective crops the breeding of which is discussed in detail in the latter part of this bulletin.

Note.-- Blank forms in which to record the various classes of notes devised by each station, firm or individual, should be numbered, as Minn. form No. 7, or Minn. form No. 139, for use in testing varieties of wheat. A "Form Book", into which a copy of each new form is pasted and given its serial number, serves to keep a record of blank forms devised. When a blank form is revised, the new form can be pasted over the old one, or, better, it can be given a new number, and a note made on the new and old sheets stating that the form under the new number takes the place of the old form.

Fig. 39. A view of a portion of the Minnesota Agricultural Experiment Station farm, showing fields, series and plats for the year 1899.

Fig.39. Drawing of a field on an experiment farm, showing permanent divisions. Each year the grain crop, forage crop, pasture or breeding nursery on any given small field can be shown by writing in that field the name of the crop.

Fig.40. Showing how a field on an experiment farm may be permanently divided into Series I to XI, on which varieties of field crops are grown in test plats. The square plats are especially adapted to running the plats north and south every other year and east and west the alternating year.

Fig.2 . Solid lines illustrate a block of land as divided into plats running north and south and planted to wheat in 1905.

Dotted lines illustrate the same block as divided into plats running east and west and planted to corn in 1904.

Fig.4. Long Series, with Cross Plats.

Field A, Series VIII, showing division into plats 1, 2, 3 etc, 2 x 8 rods, as sown to varieties. Where a section of the series is unusually moist or rich, or thin and poor, a broad plat can be skipped, sowing it to bulk seed of the same species, possibly to some new variety which it is desired to increase for field planting and distribution.

With the system of hand plats the land can be so divided as to have a rotation of say four years. This will then make it practicable to grow a given species not oftener than once in four years, and the soil can be kept free of weed seeds, fertile and in good mechanical condition for that crop. By using the meter as the unit all measurements and areas may be expressed in metric decimals. The small sizes of the plats makes possible the division of the land into plats of the different sizes. Thus the 100th acre plat, can be divided into two 200th acre plats or four 400th acre plats. Or expressed in the metric areas the

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Form, Size $8\frac{1}{2}$ x 11.

FIELD VARIETY YEAR BOOK, 1904.

Field T - Series VII.

WHEAT.

Name of parent.	Minn. No.	Name.	Plot No.	Size plot.	Date sown.	Amt. seed.	Per cent leaf rust.	Per cent stem rust.	Per cent lodged.	Date ripe.	Date cut.	Height.	Type.	Per cent smut.	Picked grain.	Yield per plot. Straw.	Yield per plot. Grain.	Yield per acre. Straw.	Yield per acre. Grain.	Remarks.
Haynes' Bluestem	169		1	1/40	4/16	$1\frac{1}{4}$	98	0	0	8/17		43	Bluestem				30		20	
Bolton's Bluestem	146		2	1/20	4/16	$1\frac{1}{4}$	98	0	0	8/17		45	"				65		21.6	
Haynes' Bluestem	662		3	1/20	4/16	$1\frac{1}{4}$	98	0	0	8/17		44	"				76.5		25.5	
Glyndon 753	666		4	1/20	4/16	$1\frac{1}{4}$	98	0	0	8/17		40	"				65		21.6	
Haynes' Bluestem	671		5	1/20	4/16	$1\frac{1}{4}$	96	0	0	8/17		39	"				62		20.6	

Specimen pages of Field Variety Year Book, for wheat. The box headings on the columns show the notes which are to be filled in; the open spaces in the blank form show the notes taken in breeding wheat. (See Table under the respective crops other than wheat.)

Preparation for Field Notes.-- With some species all nursery notes can be taken by inspecting the growing and ripening plants. In other cases only such notes as height, earliness, etc., are taken in the fields. Not infrequently samples of average plants, fruits, seeds, etc., are secured, that their characteristics may be recorded in the laboratory. In other cases records must be made of the yields in weight of specific areas. Not infrequently the ripened product must be taken to the laboratory and tested for quality. A system of tests and notes must be devised for each species. The Field Variety Year Book is the annual key to the field work in testing varieties of the various species. See page___, also Fig___.

Maps of Experiment Fields.-- Prof. J. H. Shepperd, of the North Dakota Experiment Station, has demonstrated the importance of keeping an exact scale drawing of the experiment farm with its fields and plats each year, showing the location of every plat, variety and experiment. This sometimes avoids errors. Such charts show the exact environment of each plat or variety each year and also the history during previous years of the exact plat of land bearing it.

Viable Seeds a Necessity in Testing.-- To insure uniform, good stands, the seeds used in variety testing must all be viable. Great care is necessary in harvesting varieties and in drying and storing the seeds so that their power to germinate may not be impaired. In case of varieties secured from outside sources, it is very often necessary to grow the variety one year so as to have fresh seeds of sufficiently strong viability to use the second year in the variety field tests -- or to plant in nursery foundation

beds. This also gives the newly introduced variety a year in which to adjust itself to its new environment, as is discussed elsewhere.

Every breeder who tests varieties by planting their seeds should test the seeds used for viability. The Seed Laboratory of the United States Department of Agriculture can advise as to the length of the germinating period of many varieties and as to apparatus and methods to be used in testing seeds for viability. While some varieties are tested with difficulty, fairly accurate tests may be made before planting most seeds; and records should be made of the percent of germination in the field.

There is often need of a knowledge of how thickly to plant each variety, as some varieties stool or branch much more than others of the same species; some have larger seeds than others; and owing to their form or the character of their surfaces some varieties pass through seeding machinery more rapidly than others. In regions with sufficient moisture so that broadcasting places the seeds under favorable conditions as to moisture, seeding small plats by hand enables the workman to distribute evenly the quantity of seed weighed out for each plat. Where drouthy conditions make machine drilling almost imperative, that the seeds may all be carefully placed in moist earth, remnants left by the machine not running all seeds out in going once over the plat can sometimes be sowed broadcast and covered as by means of the harrow, that the full amount of seeds desired may be planted.

Planting variety test plats.-- The planting of larger plats of one-twentieth and one-tenth acre of field crops for testing varieties may be done by the ordinary one-horse or two-horse planter, drill or seeder, or by such machines remodeled so as to

plant accurately the desired amounts of seed of the different species at such definite depths as may be decided upon. Thus, the grain drill, the corn planter, the potato planter, may be made to serve well in planting in a uniform manner some of the field crops. There is need of the invention and construction of both hand and horse grain-drills and of other machinery for accurate test planting so made that they may be adjusted to accurate planting of different amounts of each kind of seeds of the grains, grasses, clovers and root crops. The principal part needing perfecting is the force feed, and this should be capable of so adjusting as to plant (a) each desired amount per acre of each kind of seed, or to plant a given number of seeds in hills at such distances apart as may be desired; (b) to give a record of the amount per acre planted of each kind of seed; (c) to be easily and accurately adjusted to different amounts of seeds and to seeds of different sizes; and (d) to be easily cleaned of remaining seeds, that the seeds placed in the planter and those removed may be weighed and their difference show the amount actually planted. A table of the amounts per acre of seeds of each size, form and weight of each species should be developed, that a printed copy may be tacked on the seed box, so that the plant breeder may adjust the machine to plant an even number of seeds or to plant a given weight of seeds on each plat, as he may choose.

A two-horse drill with corrugated rolls for "force feed" or other better feeding device, and eight and one-fourth feet wide, planting a rod wide at each round, or a similar drill two and one-half meters wide, planting five meters wide at each round of the team, is a convenient size for plats to be planted with power machin-

ery. Hand drills especially devised so as to be adjusted for planting even amounts at uniform depths of the various field as well as garden seeds may meet similar needs, and in many cases are preferred to the machines drawn by horses, even for planting test plats of grains and other field crops. Small machines supplied with gasolene or electric power might be devised with which to plant these plots most accurately and expeditiously.

Any experiment station or private breeder of field crops desiring to secure a new seed drill, a corn-planting machine, or a hand drill adapted to planting variety test plats of field crops, should write inquiries to State Experiment Stations and to the United States Department of Agriculture for advice as to the best available machine for the varieties he desired to test. There is needed a central agency, charged with the duty of keeping informed concerning all devices designed for use in plant breeding and with the further duty of assisting experimenters in carrying out the invention and construction of suggested machines and devices for which necessity may arise. Few of these devices will be needed in sufficient numbers to warrant the expense and trouble of securing patents, and thus development and manufacture must be encouraged by the public institutions which have assumed the task of developing plant breeding. Several devices produced by the experiment stations are illustrated in this bulletin.

There is some satisfaction in the thought that the range in the amount of seeds planted may be either side of the best average amount, yet there is especial need of a better knowledge of how to vary the weight and the number of seeds per acre for varieties having seeds differing in size, and there is need of planting ma-

chinery with which the amount of seeds planted may be easily controlled and recorded.

Cultivating variety test plats.--It is not only desirable, but important that the productivity and preparation of the soil used for testing varieties of most crops, the manner of planting and the method of cultivation should be somewhat better than on the ordinary farm; because our farming is constantly being improved and because the breeder should lead up to better things by providing plants and animals of better breeding to be used in an enhanced farming business where plants quickly respond to a more productive soil; also because better breeding leads to better culture.

Plats of all hoed crops, as corn, sorghum, potatoes and cotton should be cultivated uniformly, so as to give uniformity in depth and in dirt mulch, and they should be kept scrupulously clean of weeds. Crops closely drilled or broadcasted must be kept clean of weeds mainly by the rotation and cultivation of previous crops. Where large weeds appear, they must be removed, with the hand, hoe, or spade. As a rule no cultivation is given crops thus planted, from seed time to harvest. In some cases, where a low portion of a plat has been injured by excessive water, or where weeds, diseases or insects have seriously injured a portion of the plat and the remaining portion is left uninjured, the weak portions may be cut before the plats are harvested. In this case the greatest care is needed to follow straight lines in cutting out and at once measuring and recording the remaining areas, that the record of the actual crop harvested may be correct.

Taking field notes.-- As in the case of nursery plats, it is wiser to record too many rather than too few notes concerning

variety field plat tests. All notes, as of the sizes of seeds, quantities planted per acre, and the quality and the viability of the seeds, as well as the new name and numbers, (and also the popular or general name, the class) of each variety should be carefully recorded at the time of planting, in the Variety Year Book, and where practicable on a stake at one or both ends of the plat. As a safeguard against loss of the Variety Year Book, the plat of the land and the numbers and names of the varieties should also be filed in a separate building to serve as a duplicate key to the plats.

In case of crops drilled or broadcasted, when the plants are several inches high, careful notes should be taken of the thickness of the stand. Some one variety which has the appearance of having a good stand may be taken as a standard, and other plats may then be compared with it on a percentage basis. If this plat is placed at say 85 or 90, the others can be placed above or below. Plats in which the plants are too numerous may be placed at above 100. This most vexing matter of securing an even or an equitable stand of a lot of varieties with seeds of different sizes and with different degrees of germinating power should be studied at the time of taking notes on the stand secured in relation to the sizes, weights and forms of their seeds and in relation to the amounts actually planted, and also in relation to viability as shown in germination tests made previous to planting. In some cases the stooling habit of the respective varieties should be studied and notes made on their relative power to "thicken the stand by stooling."

In case of varieties planted in hills or thinly in drills, as corn, sugar beets, etc, enough seeds should be planted so that the plants may be thinned to a uniform number of plants per row or

per acre. And in rare cases where the expertness of the planter, or previous experiments warrant, the respective varieties can be planted, or thinned to that thickness under which each will have its best opportunity to yield well.

The note taking during the growing and maturing season must be suited to the particular crop and to the qualities in which improvements are sought. Under the respective crops mentioned on future pages will be given suggestions as to what points to cover in the respective classes of varieties. Some notes require attention at a certain time. Thus, records of the rust in cereals should be taken on such date or dates when the amount of injury can best be predicted from the appearance of the rust showing on the blades and stems. Notes on ability to stand erect, as in seasons when much rain causes lodging of grain crops, must be taken after each storm. And some consideration must be given as to whether each earlier or later maturing variety was at that stage of its growth when most susceptible to being broken down by the wind. Such notes as those on time of flowering and time of ripening cannot all be taken in one day, but the series of plats must be visited at frequent intervals.

Notes which are not actual measurements should be in percentages where practicable. Whenever possible two observers should work together in making notes which are the result of ocular inspection, so that judgments of each may be checked up by the other. By both forming their minds as to the percentage before either speaks, and then adjusting differences, these "team judgments" may be made with a good degree of usable accuracy. In very important cases three should thus work together. Soon the sharp competition of the

two or three minds in settling differences in judgment results in so educating the eyes of both to see and the judgment of both to weigh accurately the qualities in question that the two minds work in close harmony. And this education is a very important part of this plan to team work. Observers gain a habit of and pride in doing highly efficient work.

Securing seeds for next year's tests.-- In many cases each variety continues in the test plats for a series of years. Slight mixing in an ordinary threshing machine sometimes seems almost inevitable. Where mixing has occurred it is necessary to select by hand sufficient seed from the plat just before harvesting so that the test plat the next year may be planted with this selected seed. This not only avoids mechanical mixture of varieties of such crops as flax, wheat and oats, but it effects a selection of the largest healthy seeds which adds slightly to the value of the strain. Though this selection is not so effective as that carried out in the nursery plats, yet experiments by Zavitz and others show that by this means some improvement of even close pollinated species is accomplished. With species which are occasionally or freely cross-pollinated, this selection is more effective and in crops which are produced for their seeds, this plan of saving seeds for the next year's test plat is especially important.

And the experiment station or other public or private breeder who has established a valuable new variety, can by this method keep pure, or make pure and true to type, stocks of the new kinds for future distribution. Thus, the Minnesota Station was requested to supply fresh stocks of Minn. No. 169 wheat, distributed several years later, but which on many farms had become mechanical-

ly mixed with Fife and even with bearded varieties, making it less salable for seed and of less value to sow in sections where it yields materially more than do the common varieties by which it was adulterated. This fresh seed thus provided was not only pure "Minn. No. 169" but it had been slightly improved by this further selection of best spikes and best seed from these spikes.

The grower of pedigreed seeds who will follow the above general plan and will thus hand pick sufficient seed one year for the next year's planting, and from it grow sufficient seed to be sold for seed the third year, will always have a claim of uptodate superiority and purity of type for his stocks of that given variety both to insure better prices and more certain sale for all the seed he raises. A statement in his advertising that this continuous selection is carried forward will help to sell his seeds at preferred prices.

This method of hand picking previous to harvesting or threshing is expensive, and where there are many varieties and very careful laborers are not available, much mixing and wrong naming of varieties sometimes occurs. Immature seed also is often picked. And in some cases it is not practicable where the breeding establishment has a large number of plats coming forward at nearly the same time to secure a sufficient number of temporary laborers capable of picking the best spikes or panicles from the ripening crop. Another method which is often much more satisfactory is to have the type of each variety plat correctly marked in the field book and then after grain has matured in the shock, save out a few bundles from the plat and store these away until time for careful selection can be had. The bundles for each plat are then laid out on a table

in good light and all foreign types eliminated. The pure types remaining are then threshed in the "centgener thresher" and the seed saved for the next year's planting. The weight of seed thus taken from the plat is of course added to the bulk threshed in the larger machines before yield per acre is figured. This method is cheap and can often best be used by the farmer and grower of pure bred seeds in keeping varieties pure.

All seeds of wheat, oats, barley, flax, etc., for variety test plats are graded with a machine such as the "Wonder Grader", which removes all but the heaviest seeds. (See Fig.___) Electric, gasoline or hand power can be used to run this grader. The selection made with the "Wonder Grader" has slight effect in improving the variety, which is worth something.

CORRECTION OF FIELD PLAT YIELDS.[a]

In testing the yields of varieties in the field the theoretical condition assumed, and striven for in practice, is that all conditions tending to modify the yield shall be reduced to equality, so as to allow the actual difference in yield to be an accurate expression of the true difference in the yielding power of the varieties tested. The large amount of space and time required for these experiments judtified an inquiry into the accuracy of such results. If there are causes of difference in the environment, whose effect upon the yields is greater or as great as the inherent difference in the varieties, the experiment becomes worthless, except as an average of a series of years may roughly indicate the better yielding kinds. Among the outside influences are, First,-- preparation of the soil, fertilizers applied, amount of seed sown, depth and method of sowing, time and care in harvesting, handling, threshing and weighing. All of these conditions can be rendered uniform by careful conscientious work. Second,-- climatic influences. These are uniform for the experiment of one year. Third,-- soil conditions. Here we find a serious difficulty. Equality of soil conditions is striven for by selecting an area with very gentle slope

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[a] This is an original publication, a method of correcting the yields of varieties necessarily grown in series of plats on undulating fields. This method was devised and used by Mr. H. H. Chapman, then superintendent of the Branch Station at Grand Rapids, Minn., and the language and drawings are largely his.

and as uniform in other respects as possible, on which there has been the same system of cropping for some years previously. But uniformity can only be approximately attained here because most experiment farms were not chosen with a knowledge of the future needs of land providing for uniform plats, and too often the fertility of the soil varies from rod to rod in all directions. But even the supply of plant food is more uniform than the moisture content, which is influenced by slight elevations and depressions, or gradual slopes which do not appear conspicuous to the eye, and also by subsoil strata.

The relative amount of moisture the soil holds in readiness for the crop at different periods of the growing season has more effect on the crop than any other single influence, especially in a region subject to periods of drouth; and this effect is equally pronounced at different points in a field for any one season. Certain portions of a field may yield the best crop one year and the poorest crop the next, due to the varied balance between the amount of rainfall, the elevation and the drainage of that particular portion. The texture and character of the soil, whether clay or sand, affects varieties differently, some doing better than others on a heavy soil, while on light soil the yields may be reversed. But usually a field is available where such variations of soil texture are slight and can be disregarded. The variations in the moisture content of the soil, however, no matter how level the land is, are sure to be much larger and more disturbing to the scientific accuracy of the comparisons. The recognition of these facts has caused many scientists largely to discredit such comparative yields, although yield tests are a matter of great national importance.

Increasing the size of the plats does not offer a solution, for acres will differ from each other as surely as any smaller sub-division, often more. However, the influence of too much border is an argument against too small a plat.

There remains the method of using check plats to eliminate if possible the difference in yields caused by these variations of soil and moisture conditions. But this method will not succeed unless systematically and intelligently applied. It will serve merely to show the experimenter that his comparisons based on actual recorded yields are not trustworthy.

Check plats, all of which are planted to the same variety, should, if the controllable conditions mentioned are made uniform, give equal yields, and the differences in yields which such check plats give can be attributed to the variations in the soil and moisture conditions. Check plats may therefore be used as possible bases of correction, by which the effect of such variations may be eliminated from the comparison and the actual comparative yielding power of each variety be closely determined.

But unless yields of these check plats can be compared with the yields of the varieties so as to get at a true basis of correction, the original figures should not be modified. It is believed that a plan based on the following suggestions can be ap-

Fig.1. (With original MS. Drawing not yet made.)

Fig.2. (With original MS. Drawing not yet made.)

plied in correcting plat yields in many cases.

Assuming that the field used is a rectangular one with the plats running across it, as in Fig.___, variations of yield due to soil and moisture will occur from end to end of each plat and from plat to plat lengthwise of the series.

The possibility of variation from end to end of plats is greatly reduced by having a narrow series and consequently short plats. The variation from plat to plat may be measured by means of the check plats. The more frequent and the narrower the plats, the nearer the check plat yields will represent actual soil conditions. Plats one by eight rods on series eight rods wide are the most used size and the following statements apply to them.

The variation in the productiveness of the soil from plat to plat across the series may be expressed by charting the yields of the check plats on cross section paper at regular intervals and correcting these points by a curved or broken line extending from one end of the series to the other. The variety yields on the intermediate test plats may then be corrected by using this check plat curve as a basis. Stated in detail, the method is as follows: Plat the yields of the check plats on cross section paper, the plats being spaced and numbered from left to right and the yields scaled from below upward, as in Fig.___. The points marking the yields of the check plats may then be connected by lines. Whether these points are connected by straight lines or by curves and whether such curves round upward or downward between points will depend somewhat upon the relative position of the adjacent check points on the chart and somewhat on the comparative soil conditions in the field, as determined by the experimenter upon observation. Experience and records of previous years may be a help in drawing the curve.

Having determined this curve, the points where it intersects the lines 2, 3, 5, 6, etc., indicate the yield which the check crop would have made had it occupied these plats, instead of the varieties planted there. These yields which in this case are taken off in tenths of bushels are entered in column 3, Table___, opposite the respective variety test plats. The average of all the check plat yields is then found by adding together the actual yields in the check plats, and dividing by the number of plats.

Considering this average yield of thecheck plats as 100 percent or 1,000, the ratios of the theoretical yield in column 3, to this average are determined and expressed in the percentages shown in column 5, which represents the amount by which the actual yield of the variety is increased ordiminished from its true yield, by the effect of soil and moisture conditions. Thus the average of the check plats being 88.5 by the yield of No.17, 110 bushels is only .904 of its true capacity, since the soil value of the plat is below normal. The yield of the variety under test on each plat in column 6, is therefore divided by this percentage, thus giving the corrected yield in column 7, which for No. 17 would be 121.6 bushels instead of 110 bushels per acre.

These corrected yields, while they cannot be expected to eliminate all differences except those due to the productive power of the variety, can with honesty be claimed to be much nearer this true comparison than the original yields. There are many who would

TABLE NO. 15.

1	2	3	4	5	6	7	8
No. of plat	Name of variety plant- ed.	Actual and inter- polated yields of check plats from curve.	Average of actual yields of check plats.	Relative value of soil on test plats as shown by check plats.	Yields octained from var- ieties on test plats.	Corrected yield of variety which el- iminlates soil vari-	Rank of variety based on field.
		Bushels per acre.	Bushels per acre.		Bushels per acre.		
1	Check	120	88.5				
2	--	113	"				
3	--	107	"				
4	Check	100	"				
5	--	95	"				
6	--	90	"				
7	Check	88	"				
8	--	88	"	.994	96	96.6	
9	--	90	"	1.017	84	82.6	
10	Check	93	"				
11	--	99	"				
12	--	101	"				
13	Check	100	"				
14	--	96	"				
15	--	91	"				
16	Check	85	"				
17	--	80	"	.904	110	121.6	
18	--	72	"	.813	115	141.5	
19	Check	65	"				
20	--	61	"				

question the scientific accuracy of deliberately altering definite figures, and substituting therefor theoretical deductions of yields. But the success of scientific experiment depends upon eliminating all known causes of variation except the one which is to be tested. It is believed that experimenters will be convinced of the greater scientific accuracy of this method as compared with accepting the results of field tests, without modification, a plan too often blindly followed for fear of departinf from facts.

No cause of variation, such as damage to crop by insects or disease will cause any greater variation to such corrected yields than to the face value yields. Such influences really invalidate the experiment under either condition, and the fact that at best this method is an approximation, which is cheerfully admitted, is no argument at all for rejecting it, if it can be proved more accurate than the original yields as a means for getting correct comparisons.

In case two series are planted, a curve could be worked out for each series. But the yield of the check crop can be reduced to a common standard, the curve merely being extended to embrace the plats of both series. Or each may be worked out separately and then the yields of one reduced to the terms of the other by dividing the yield of each variety on the second se ies by the average yield of the check plats of that series and multiplying by the rates between it and the average yield of the check plats on the first series.

It might be well to collect data in an effort to determine the soil equivalent of parmanent sample plats. The curve made in years when the plats are used for variety tests as a record of the yielding powers of the respective plants may be supplemented in the following manner: In alternate years when some crop is planted uniformly over the series, in rotation with the variety plats of the crop under test, the plats may be marked off and harvested separately. Their yields platted in a curve will show the value of the different parts of thefield for that year and crop. A curve for each of several years in which the yields of check plats ~~are~~ were recorded, and of other years in which the yields of a crop similar in all plats were recorded, would thus give data as to the soil value of each check and test plat in the series.

Where sufh records have been kept for a sufficient number of years, the soil value or a coefficient of production under different conditions of rainfall and temperature of each plat in a variety test series might be so definitely determined as to warrant its direct interpolation into the yield for any year, without averaging data from one plat with data from another plat between which there is no relation excepting geographical proximity.

Without such data, however, the yield curve and averages of calculated soil values afford an immediately available method for more nearly approximating the truth in testing varieties.

H. H. Chapman.

INTERPRETATION OF RECORDS OF VARIETY TESTS.

There is art as well as science in the interpretation of the performance records in testing varieties. The first year may show lack of hardiness, of yield or other character which shows the varieth not worth trying further for its general efficiency. If it is to be retained in the tests it must be rather with the hope that it may be useful because it has some positive character which might be introduced by hybridizing into varieties needing that character. Varieties somewhere nearly alike in value in a given locality can not be compared from a test of a single year. The usual course where seeds of varieties have been assembled from a distance is to throw out few varieties which produce seed the first year. Often the records of the first year are used only temporarily, to be discarded after the second and third, or the second, third and fourth years are available to yield tabulated averages of yield, etc. Often standard varieties are kept in the field plat tests for many years, in part to keep a record of their continuity or variability in yields, and partly that there may be a group of standard varieties with which newly introduced or newly originated varieties may be compared. When new varieties have gained a place among the standard varieties by having so excelled in yield and other points of excellence that they have been successfully introduced into commercial use they retain their place in the variety tests as standards of comparison.

Variety Ledger Accounts.

To make the necessary records so that partly by merely inspecting the records and partly by actually casting up average figures ledger records are necessary. Most of these can be on loose

sheets, and where practically these should be stored for most of the year in a fireproof room or vault. There are many reasons for choosing the ordinary letter sheet as the size of these ledger sheets and tabulated forms on which to record the general facts and figures of the groups of varieties.

VARIETY LEDGER ACCOUNTS.

Ledger accounts and summaries of yields, grades, analyses, etc., are tabulated by years. The blank forms below illustrate some general manners of tabulation. These sheets with proper indices may be filed in a vertical filing system. Schemes for ledger sheets must be devised for many different conditions. The methods of displaying variety averages year by year used in the reports of Ontario Agricultural Colleges and by various other plant breeding establishments will serve as examples to aid in devising systems for temporary purposes, and for use year by year. These can be found by referring to the annual reports made by Professor Zavitz of Guelph, Ontario, and others.

CHOOSING THE BEST VARIETIES FOR DISTRIBUTION.

These living agencies, the varieties, which may be stable in their characteristics, or may change during a series of years, require that records be kept consecutively and on the same general plan. Thus, comparisons may be made showing whether a given "candidate" for distribution to growers is gaining or retrograding from year to year as compared with the standard or rival varieties. In Fig.____ is shown a plan for recording on yield. Quality of grain, baking quality, or other character, can be recorded in a similar manner.

When a group of vegetables has been in variety test plats for two or more years, a plan of summarizing yields, qualities, disease resistance, and other characters, is necessary. This may be accomplished by means of loose leaf ledger records on which are recorded the various items as hardiness, yield, quality of product,

VARIETY LEDGER SHEET.

Wheat Averagesof Yields, 1907--1897.

Name of Variety.	Minnesota Number.	1907—1906 2 Year average	1907—1905 3 Year average	1907—1904 4 Year average	1907—1903 5 Year average	1907—1902 6 Year average	1907—1901 7 Year average	1907—1900 8 Year average	1907—1899 9 Year average	1907—1898 10 Year average	1907—1896 11 Year average
Powers Fife	66										
Glyndon #763	163										
Haynes Blue Stem	51										
Haynes Blue Stem	169										

etc. The ledger summaries of tests of a group of varieties thus become complex. The study of the general value per acre to farmers, also of values to manufacturers and consumers, becomes a problem requiring a combination of skill and equipment along various lines. With persistent effort, tabular arrangements can be devised which will greatly aid in deciding upon the relative values per acre of the respective competing varieties in a competing class. In score card schemes great care should be exercised to keep the larger weight on those qualities which mean value per acre. At the same time, it is sometimes necessary to temporarily give greater score card weight to characters especially in need of improvement. Rules for making tabular ledger schemes are less essential than active efforts to study out a scheme for making prominent those characters which meet the particular case in hand.

Each character is thus so recorded on a separate sheet as to show clearly the one character under comparison. Then on another sheet the varieties are arranged in order of yield, or other expression of general merit or value per acre. Thus, it is sometimes practicable to reduce yields, quality, disease resistance and other leading characters to a percentage basis, and then, after combining the percentages with score card weight factors, reduce the weighted factors to a simple factor or figure for each variety. As a rule, however, the breeder whose judgment has been trained by long contact with a given group of varieties can effectively select the variety of greatest general value to growers by assembling the records of the various qualities in a tabular statement, and by inspection, together with some averaging of annual figures, decide which are among the best. Only in rare cases is it necessary to

figure so as to give mathematical weights to score card points; and the trouble of figuring even then needs to be taken only in case of the relatively few most nearly competing for the honor of being distributed.

Much "red-tape" is made unnecessary by long experience. And administrative officers are wise to arrange for long tenure for public servants to whom is delegated the work of breeding one or more species of our economic plants or animals, representing as they do such vast annual production. Each beginner in breeding should content himself with breeding only one or a few classes of plants, that he may become a highly trained specialist in that important work and be able to retain his supervision of combining characters in that class of species into highly valuable and greatly artistic products. The work of breeding is to rapidly increase, because the profits to the public are proving so large, and in the end each line of breeding will give wonderful opportunities to the highest talent.

Varieties which have been longest in the tests may be compared with each other for a longer number of years than they can with varieties introduced at a later date. Since seasons greatly modify the yields, quality, etc., the varieties introduced at a later date should be compared with those introduced earlier only for those years in which all have been grown, that the comparison may be fair to all. Occasionally an accidental loss of the record of yield or other quality of a variety for a year, which often occurs in climates subject to years of drouth, necessitates making a special ledger sheet on which all varieties are left out for that year, so as to better compare the relative values of that one variety.

Judgment as to which of two varieties is most valuable per acre cannot be formed by taking into consideration only one quality, as yield; though yield is often of more importance than all other qualities combined in making choice between several varieties all of which are reasonably satisfactory inquality. In wheat, the market quality of the grain, as shown by its appearance, or what is commonly known as grade, including weight per bushel, size of kernels, condition of bran, etc.; the ability to stand erect on rich soils in moist seasons; the power to resist rust; the quality of the flour, as shown by the strength of its gluten, its color, its flavor, and its ability to rise into a fine loaf; and even the adaptation to milling purposes and to the methods of making the bread into loaves; and other qualities, must be taken into consideration in forming judgment as to which of numerous varieties has the largest general value to the farmer, miller, and consumers of the State. And these qualities must be considered for each of the different soils and climatic conditions for the whole area for which the variety is desired.

That experiments at one experiment farm are sometimes inadequate was demonstrated in variety tests at the Minnesota Experiment Station, and the policy has therefore been adopted of securing cooperation among the branch stations within the State and with the State Stations in adjoining states. The wider cooperative testing already in operation with spring and winter wheat, durum wheat, corn, timothy, etc., is further proving this important fact.

The cooperation under the auspices of the Bureau of Plant Industry of the United States Department of Agriculture, of the Minnesota, North Dakota, South Dakota, Iowa, and Wisconsin experi-

ment stations in the testing and breeding of varieties, has demonstrated that such wide cooperation is both economical and valuable. Not only are varieties being tested to better advantage, but once a variety has a record of standing first in the list of tested varieties at two or more stations, its pedigree reputation is greatly enhanced and the conservatism of farmers in widely adopting it is more completely overcome.

The success of Minn. No. 13 corn, originated in the Minnesota Station, chosen at the South Dakota Experiment Station as the variety for distribution along the northern zone of the Dent corn belt in that State, as well as in Minnesota, the place of its origin, is a case in point. A new variety of flax produced at the Minnesota Experiment Station likewise has proven equally useful in several states. Varieties of barley, as Oderbrucker and Mandscheuri barleys, tested, improved and found superior in Ontario, Wisconsin and Minnesota, are made more prominent by records concerning them which show their superiority at several State stations. Their values were thus emphasized not only for growers, but also as foundation stocks from which to breed new varieties both by selection and hybridizing.

Free seeds and free plants have helped keep the farmers in the habit of paying only 5 to 10 cents extra for plump and well cleaned seed of wheat. This was amply proven when the Minnesota Experiment Station offered a new pedigreed Blue Stem wheat, Minn. No. 169, with an authenticated record of an increased yield of 18 percent. Only one man in four, 300 out of 1,200, chosen because they were known to be growers of good wheat, would purchase this variety at one dollar and a half per bushel in four bushel lots,

when common wheat was selling at about 75 cents. They needed to be shown that the new seeds, thoroughly proven to be yielders of more value per acre, should be sold at a higher price thancommon wheat. Many of the men who purchased this wheat have sold seed wheat in large quantities at prices thirty to one hundred percent above the prices offered at the elevator for the same wheat. These men now see that had the State Experiment Station given away this wheat, no higher prices than for common Blue Stem wheat would have been established for the pedigreed seeds, and that there would have been no one making a business of growing it for sale. Since the extra price pays the grower of this pure-bred variety to grow it with care, and widely advertise it for seed, the profits make distributing it a commercial business.

Many men have found growing this variety, and Minn. No. 163, also Minn. No. 25 Flax, and other new varieties distributed by the Minnesota and the neighboring Experiment Stations mentioned in cooperation with the Bureau of Plant Industry, of the United States Department of Agriculture, profitable. And this is to the advantage of those to whom they sell pedigreed seeds, because otherwise most of them would not be induced to purchase and use the new varieties. The experiment with this wheat and with other wheats, corn, barley, oats, and flax, have shown that there may be a special price on pedigreed seeds as on purebred animals; that men may find profitable business in distributing the best seeds as they do pedigreed livestock. Free seeds and free breeding stock help to paralyze private enterprise in pedigreed seeds and live stock.

Creating new varieties of plants and new breeds of animals and introducing varieties and species of plants from other countries

at Government expense should not be confounded with free distribution. The United States Government and the States may properly cooperate in creating new varieties of plants and new breeds of animals without interfering with individual effort in producing pedigreed seeds, plants, and animals for sale. In fact, the valuable new varieties which the Government and the States import and create may be used effectively in aiding the pedigreed seed business to gain such a strong hold that it can supply to all growers the best improved varieties at moderate and equitable prices. The Government and the States need the closest cooperation from growers of pedigreed seed and pure-bred nursery trees in the wide introduction of the many new varieties they are introducing from abroad and creating by breeding; just as they would need cooperation by breeders of pedigreed livestock if they aided in creating improved families or breeds of domestic animals. Our breeders of pedigreed livestock are a most useful class of business people in effecting improvements in animals, and growers of pedigreed seeds as well as seed merchants and nurserymen are becoming just as essential a part of our business affairs.

Free Distribution of Plants in Iowa.

An extensive experiment by the Iowa Agricultural College in the sale at very low prices of recently imported Russian fruit, forest, and ornamental trees, gave most valuable facts concerning the distribution of seeds and plants. By selling these trees at lower prices than those charged for good trees by nurseries, the college lost the sympathy and support of many of the nurserymen, or growers of pedigreed trees, of the State. This early distribution,

before there existed an adequate number of public grounds on which new varieties could be tested, was in part that the new varieties might be given wide trial. Naturally most of the new things were not valuable in the regions to which they were sent. In fact, the main value now claimed for the experiment, as it relates to fruits, is that many of the varieties introduced from northern Europe brought hardy blood valuable for hybridizing with American varieties which are superior in yield and quality of fruit, though lacking in hardiness. The low prices, almost gifts, evidently relieved responsibility from those conducting the distribution and led to the sale of mmny varieties before they had been tested. The sum of the results in varieties of hardy Russian fruits immediately valuable for the middle Northwest, as introduced by the Iowa Agricultural College in the early eighties, was somewhat disappointing from the standpoint of securing superior new varieties of improved fruits. But the facts demonstrated as to methods of distributing plants are very valuable. In this case the following lessons were learned. (1) Varieties must not be distributed until rigid trials have been made under scientific direction. (2) Only varieties of staple crops which are better than those now in use should be distributed. (3) The distribution of varieties which prove unsuccessful is wrong and unfair to growers. (4) Distributing varieties which do not succeed ruin the reputation of the breeding and distributing agency. (5) Selling seeds and plants at prices below those which can be afforded by commercial growers of seeds and nurserymen and seed and plant merchants results in disturbances to business and irritation among the improvers of plants.

Professor Budd, under whose charge the Iowa experiments with fruit introduction were conducted, saw that the north European fruits and plants thus placed in the hands of many nurserymen and farmers would hybridize with the American varieties of good quality but were lacking in hardiness, and that a large number of hybrids between these two classes of varieties would thus be produced that would be worth many times more than the possible aggregate cost. And many hybrids are being produced by numerous public officials and by private plant breeders, already providing a large mass of hybrid stock from among which parent plants will doubtless be found from which will be developed valuable clonal varieties of apples, plums, pears, and even varieties of forest and ornamental trees and shrubs.

The free distribution of pedigreed animals to farmers by Mr. J. J. Hill in new sections of Minnesota and North Dakota has demonstrated one very important fact applicable also to seeds. The pedigreed male animals thus distributed serve only for their own lifetime, and on native and grade females. When they pass out of use there is only grade stock left. There is little continuity of upgrading by the repeated use of pure bred sires; and no pedigreed herds are established. The continuity of upgrading to one type, which alone can bring uniform and average high excellence, is entirely wanting. The new owners of pedigreed animals, having had no experience with pedigreed stock failed to appreciate them. Very few, indeed, were induced to establish pedigreed herds, and in a decade there was no general improvement discernible in the neighborhoods into which Mr. Hill so generously placed animals of splendid breeding. The farmers were not required to enter into cooperation to produce permanent improvements.

General Facts Conerning Seed and Plant Distribution.

The different classes of species present different problems in distributing newly introduced and pedigreed varieties to all who need them. With some species free distribution may be moderately effective, though open to the weakness that no commercial interest is aroused to grow the seeds or plants for gain; and no one has the incentive to make expenditure in advertising the new sort. And with most varieties the distribution stops with the few who come especially to know of the values of the new sort. The two methods which have had wide and successful use have been distribution by sale to growers of pedigreed seeds and plants, and distribution through experiment associations. The Minnesota Experiment Station has had large success with the method of selling field crop seeds to growers of pedigreed seeds, while the Ontario Agricultural College, the Wisconsin Experiment Station and other experiment stations have had most excellent results with distribution through experiment associations and corn breeders' associations. The United States Department of Agriculture and other establishments which introduce and breed plants find ways of distributing many valuable trees and fruits by placing them free/or on a share basis in the hands of nurserymen.

1. Free distribution, or distribution at a price below value to those who ask, places the public distributing agency on a false business basis, too often political rather than economic, and tends to demoralize legitimate enterprise in the testing, production and sale of pedigreed seeds and plants.

2. Public aid, on the other hand, may be so managed as both to produce better plants, and to arrange superior business organiza-

tion and methods for testing and widely distributing pedigreed seeds and plants and animals under a splendid business system mostly in the hands of a large body of cooperating private citizens.

3. Varieties should be thoroughly tested and all eliminated which are not valuable, distributing only those in case of which there is the most positive evidence that they will be commercially more useful than those which growers are using.

4. Varieties which prove valuable for a given locality should be so introduced that the proof of their value, as determined in tests, will be used to induce people to adopt them rather than to pay high prices for attractively advertised inferior kinds.

5. The nurserymen and dealers in pedigreed plants and seeds as well as those who make a business of growing pedigreed plants and seeds should be aided, utilized and brought into cooperation in introducing new varieties, rather than ignored.

6. The universal excellence of varieties distributed; the agreement among agencies interested in pedigreed varieties; square dealing with growers to whom seeds and plants are sold; the organization of State and other associations to test and promote the development of better seeds and plants; and a grand literature on plant improvement are all necessary to overcome the conservatism of growers so that they will purchase and grow only the best seeds and plants; and never before were the agencies for plant improvement being so well organized.

<u>Experiment Associations</u>.

The method of distribution of seeds through organization of farmer students of agricultural schools and other farmers, under such names as Experimental Associations, have proven to have successful elements of the greatest value.

A general plan is for the State experiment station to supply sufficient seed for a small area, often a hand sized plot a rod square or more, to each member who cares to try that kind of seed. Each member receives two or more varieties, and he is requested to plant besides these for comparison the varieties commonly grown on his farm. There is no doubt but that this plan helps to quickly and widely distribute valuable varieties and in addition aids in sustaining a strong organization of farmers useful for other purposes. It teaches the farmer the high value of variety testing and illustrates to him and his neighbors the value of pedigreed seeds. It leads him to make a careful test on a small plat with hand test of several varieties, thus giving him an insight into this highly important scientific work of the experiment station and the seed firm. It tends, too, to make of him a student and a leader of his fellows/ It connects him in a most vital way with the experiment station work, and he becomes an advertiser and an advocate of the improved seeds and plants.

This plan recognizes the business of growing purebred seeds for sale. The members of these associations increase those varieties which prove best and soon begin the sale of pedigreed seeds at remunerative prices. It provides a splendid agency for the wide trial of the new variety, and is doing much to introduce new varieties and to interest growers generally in purebred seeds. When organized on a sufficiently large scale, as in Ontario and in Wisconsin, it serves to take the seeds of an improved variety to nearly all people needing them. It reaches even the unenterprising, because the grower of pedigreed seeds has good profits at stake in inducing his neighbor to purchase seeds at an advance over elevator prices.

The most remarkable development of this method is in Ontario. The Ontario Agricultural College has nearly 5,000 farmers in its Experimental Union. When a new variety, as of wheat, barley, oats or rye, has for five years proven best on the experiment farm it is distributed to members of the Union. Usually the farmer plants his own variety and two supplied by the experiment station. Sufficient seeds are supplied to plant a square rod, that all the work may be carefully done by hand. When the farmer has tried new varieties for three years he knows which variety yields the most value per acre and he soon has sufficient of that variety to sow a field and to begin to sell seeds to his neighbors. The records of performance of the new varieties, as tabulated in the bulletins of the experiment station and substantiated by the many experiments by members of the Union throughout the province, give the new varieties such a reputation for increases in the value of crops that the growers of the seeds can command fifty percent and upward for the seeds than they would be offered for them on the grain market; and this larger price is sufficient to induce the members of the Experimental Union to grow, prepare for sale, and sell seeds in large quantity.

This plan has been especially developed with the cereal crops and varieties thus sent out by the college cover most of the acreage devoted to the cereal crops in Ontario. Careful estimates indicate that at an annual cost of about $12,000, the crops of the province are increased by $12,000,000, one dollar earning a thousand dollars. It is a most remarkable fact that Professor Zavitz has until recently depended upon introducing superior varieties and in the improvement of these only by hand selection of the choicest

seeds from the best plats. What proportion of the resulting improved yields of the varieties distributed is due to the introduction of superior varieties and what proportion to improvements by this hand selection in the seed laboratory of the choicest seeds is a question in dispute. It seems fair to assume that the largest increase in yields has come through the introduction of such varieties as Mandscheuri barley, which from the first was clearly a better yielder than its near relatively Mandshury. The latter was introduced earlier in this country by Deam W. A. Henry of the Wisconsin Experiment Station, the former by Professor Zavitz directly from Russia. It seems probable that each of these, decades ago, originated from a single mother plant; and as in other self-pollinated varieties thus originated, that selection does not make rapid changes. As the pound sample of Mandscheuri barley imported by Professor Zavitz has spread over the province of Ontario and throughout a number of American States, so the pound samples sent by the experiment station to the members of the Experimental Union spread to the neighborhood. It is believed that the nursery breeding which Professor Zavitz has added in recent years, and which is now resulting in new pedigreed varieties, will result in much more rapid improvement than that secured by hand selection of seeds. Theoretical experiments by the Nebraska Experiment Station and elsewhere indicate that the improvement by hand selection of seeds in a self-pollinated variety originated from a single mother plant is very slight. Professor Zavitz's results, however, are so marked that the question should be kept open. Facts not yet known may give the question a very different aspect. That it pays to continue introducing varieties as well as improving old ones and creating

new ones is illustrated by the fact that Professor Zavitz has found one of the new spring wheats bred by the Minnesota Station, Minn. No. 163, the heaviest yielding among those tried during the past several years. Evidently each State station should comprehensively labor through introducing cereal cross, variety testing, selecting best heads and best seeds; choosing best mother plants from superior varieties and testing the breeding powers of each; making crosses and hybrid stocks and from among them securing the best plants and testing their breeding powers; and after testing distribute under some effective plans which will bring the improved varieties to nearly all farms needing them.

The Consolidated Rural School and Branch Experiment Stations as Seed and Plant Distributing Agencies.

It may be, if we should have a large agricultural high school and a branch experiment station in each groupnof ten counties; and a system of twenty consolidated rural schools with small school farms in each county on the average, that they could serve to aid in rapidly introducing valuable new varieties of seeds and plants. Eight or ten agricultural high schools and branch stations in Minnesota, and 1500 consolidated rural schools, each with a brief agricultural high school course would soon produce a body of tens of thousands of students and graduates who would be able to cooperate with the State and branch experiment stations in a way to serve the entire State. A body of chosen men, long experienced in growing and marketing pedigreed seeds would keep the farmers sharply up in growing the best available new creations of the plant breeder's art. The responsibility awakened by the desire to secure superior prices for the best seeds that can be grown, keeps the experienced grower of pedigreed plants and seeds, who has many sharp competitors, up to doing his best as a grower and to widely advertising his plants and seeds to all who should secure them.

Cooperative Seed Breeding and Distribution.

The rapid development of improved varieties of field, orchard, garden and forest crops necessitates a greatly enlarged pedigreed seed and plant business. The United States and State governments can with great profit to all the people greatly extend their aid not only to the breeding and testing of new varieties but also to introducing them. There is need of a greatly enlarged class of experienced growers of pure bred seeds and plants, and of enlarged

nursery and seed merchandising business; and growers should gladly pay reasonable prices for pedigreed varieties which will increase the yields of their fields, orchards and gardens.

The essential features of the plan in use at the Minnesota Experiment Station may be stated as follows:

1. Varieties of field crops newly introduced or produced by breeding are thoroughly tested at the central experiment station, at branch stations, and at such stations in adjoining States as may care to cooperate, that no varieties may be distributed except those certain of proving of value to growers. The entire stock of new varieties is kept under control until there is sufficient seed to plant a goodly acreage, say a thousand acres or more of a leading field crop, so that the distribution may be carried out with system and under a business plan which will put part of the peculiar value of the new seeds behind the widest possible commercial distribution.

2. Men to whom the new varieties are offered for sale are well distributed throughout the section needing the new variety and are chosen with care; (a) as to their general standing and experience in growing seeds of good quality of the crop in question; (b) as to their having suitable land free from weeds peculiarly noxious to the given crop; (c) as to their having buildings and machinery suitable to handling pure-bred seeds.

3. The seeds are then offered them under terms which are practical for a grower desiring to produce purebred seeds for sale. (a) They are offered at about double the prices of commercial grain or seed, or at as high prices as the growers of purebred seeds thus

chosen in open competition with each other will pay for them. (b) Sufficient seed is offered to each to make a field of two to six acres of the small grains, and of five to fifteen acres of corn, so that practical seed fields may be grown and separately harvested. The quantity sold to each, as four bushels of wheat, flax or oats, or two bushels of corn, is limited. (c) These prices emphasize the breeding value in the new varieties and educate the growers of pedigreed seeds to the plan of using higher prices to help distribute new pedigreed varieties and the desirability of securing profits out of the pedigreed seed business.

4. An associationnof growers of pedigreed seeds has been formed, called the Minnesota Field Crop Breeder's Association, and those who thus purchase seeds and enter into cooperation with the public institutions are urged to become active members. Graduates of agricultural schools who are properly situated, are especially urged to join and enter upon the business of growing pedigreed seeds.

5. Thus the United States Department of Agriculture, the State Experiment Station, the State Branch Experiment Stations, a State Plant Breeder's Association, and numerous men chosen for expert seed growing are brought into general cooperation in the distribution of new varieties of field crops which the United States Department of Agriculture and the State Experiment Station cooperate in introducing and in creating. The State Experiment Station grows a sufficient quantity of the thoroughly tested variety to supply such a large number of growers of purebred seeds that there can be no monopoly, and yet that prices may be sufficiently high to give the necessary profits to insure the production and sale of very large quantities so that all farmers can and will secure them.

That the growers of pedigreed seeds grow these new varieties in quantity for general sale direct to farmers, and also through seed dealers, is a matter of record and of general knowledge throughout the State.

6. This plan of selling certified seeds at substantial prices places the public officers who are in charge under the very proper responsibility of making such thorough tests that only valuable kinds will be sent out, resulting in Government certificates so accrediting the new varieties that growers will be aroused from their lethargy of being satisfied to grow inferior varieties of crops. The interest of growers of pedigreed seed has proven sufficient to thus support a well developed organization to promote the breeding, growing and merchandising in pedigreed seeds.

7. Placing the price rather high by an experiment station for a valuable new variety is eventually an advantage to the grower of pedigreed seeds who is chosen by the station as a cooperator, because it establishes higher prices for the seeds he will raise for sale.

8. Minn. No. 169 wheat, sold at $1.50 was thus kept out of the elevators and for a few years was in extensive demand for seed at $1.00 to $1.50 per bushel or 33 to 100 percent above elevator market prices, thus causing its very rapid distribution, carrying its added value of two dollars per acre already to millions of acres annually.

9. The prices for holding seed grain of a pedigreed variety over winter, for extra cleaning, for advertising in the agricultural and country press, for extra care in keeping the land free of weeds and in good condition to raise wheat of superior quality, and for

assisting in promoting the adoption of the improved variety generally, proved practical both to the growers of purebred seeds and to farmers who need the improved varieties. The added millions annually which the farmers are now receiving for Minn. No. 169 wheat more than they would have received from the common wheats they otherwise would be raising is as much due to the method of distributing this variety of wheat as to the work of creating it by breeding. An inefficient system of distributing it might easily have lost to the farmers one or more millions of dollars annually. The additional price the farmers paid the growers of this variety for the few bushels each secured for a start is a very small matter beside the aggregate increase in yield. A system "nearly as good" may cause great aggregate loss. Further experiments are needed in devising methods of distributing pedigreed seeds and plants.

10. With the establishment of this method of higher prices, seed dealers, who are the most active agents in distributing good seeds, have sufficient margins of profit so that their hearty cooperation and support were secured. And since seed firms within the State have farms for producing purebred seeds, publish catalogs, advertise widely and are best equipped for selling pedigreed seeds, the quota sold to them at the time of the initial distribution is several times that sold to any farmer. This legitimately helps rather than hinders their business and the seedsmen are thus identified with the introduction of each new variety. After a few years these dealers are able to secure large quantities from those cooperating farmers to whom seeds were sold and who have pedigreed stocks of known purity. The seed firms thus come to deal extensively in the new varieties.

11. The growers of purebred seeds will develop a profitable business new to the State; they will greatly assist in bringing up the average yield of the crops of the State; they will do much by testing varieties to determine which are best for each locality; they will become leaders in methods of growing better crops, and they will receive not only a substantial financial reward, but the more highly developed education coming from this expert business. And their broader touch with their fellows will make their lives more pleasant and their influence for good to their fellows more pronounced.

Organizations devoted to the task of so developing the heredity of our six billion dollars worth of plant and animal products, that the added yield from breeding alone will be a billion dollars, will be encouraged by an effective method of distributing which pays those in the business of producing pedigreed seeds, plants and animals.

The experiments in Minnesota have thoroughly demonstrated the wisdom of every State through its experiment station cooperating with the United States Department of Agriculture helping to breed all of its staple crops to higher values and establishing a class of purebred seed growers trained in the business of supplying improved seeds to the farmers.

The nation is the most important cooperating unit; the State ranks next in power and effiency in bringing about unity of effort; and the cooperative association has most important functions; and when doing "team work" with these general powers in the leadership, the individual is most effective for his own and the public interests.

Certification of Pedigreed Seeds.[a]

Experiments have been conducted with the use of certificates of lineage and yielding ability in crops, as lineage and performance pedigrees are widely used in animal breeding. In case of varieties like Minn. No. 169 wheat, where no distinguishing quality visible to the eye has been bred in along with the increased yield, these certificates are especially needed to preserve the historical identity of new varieties made from old varieties. A system of certification helps to prevent the substitution of the commoner parent variety from the new and more valuable variety.

Certificates made on forms like that in the blank given in Table 17, are sent out to the men chosen as growers of a given new variety when the seeds sold them are delivered. These men are called cooperators, and the sending out of these certificates is limited to those securing the seeds directly from the Experiment Station. Cooperators may be supplied with "certificates to second growers" upon a written request accompanied by a statement of sales, giving names to whom sold and quantities already sold, as in Table 19. The certificates are given for only two years following the first distribution to those to whom seeds were sold by the experiment station, and are never made out by the station until notified by the cooperator that a sale has actually been made accompanied by the facts to whom sold, the date and the amount sold. For this purpose a form containing both blanks may be used, the station officials filling in all the data except the date and name of the cooperator certifying to his patron, the second grower, at the bottom of the lower form marked "B". These forms are never supplied blank to

[a] See the Ontario and Wisconsin plan, also the Ohio plan under corn.

Fig.44. Seed Order Book. With carbon sheets the indelible pencil makes three sheets. One is retained in the book, one is mailed to the purchaser and one goes with the seeds to the transportation company.

cooperators, but are made out only by station officials on data supplied by the cooperator. This form of certification has proven satisfactory to the station and popular with many seed growers. As pedigree certificates assist with the sale of live stock and encourage purity of breeding, so these certificates aid in emphasizing the value of seeds of superior breeding and help to keep names true to the stock of seeds sold.

With each lot of seed of Minn. No. 169 wheat, for example, was sent a variety pedigree certificate as in Table 17. These certificates not only certify as to the trueness to name or lineage pedigree, and, through references to the bulletin named, certify to the excellence of the variety, but together with substantial prices charged, aid in placing under obligation the officers who distribute them. Station officers who thus place the name of the experiment station and their reputation at stake are induced to test thoroughly new varieties before distributing them. Since experience indicates that it is better to supply the farmers of a State or group of States with only a few of the very best varieties of a given species, there is little danger of this method too closely restricting the distribution of newly bred and newly introduced kinds of plants.

Table I. Minn. No. 163 Compared with Haynes' Blue Stem.

Eight Trials at University Farm.

Year	'95	'96	'97	'98	'99	'00	'01	'02	Ave.
Minn. No. 163 (New Strain)	42.7	23.0	19.9	25.0	30.8	34.3	24.3	24.3	28.4
Haynes' B. S. (Standard Variety)	21.6	24.6	20.4	23.3	25.9	30.5	17.6	21.7	28.2

Table III. Minn. No. 169 Wheat Compared with its Parent

Variety through Eight Trials at University Farm.

Year	'95	'96	'97	'98	'99	'00	'01	'02	Ave.
Minn. No. 196 (New Variety)	37.8	25.0	24.3	26.3	28.8	30.9	22.9	25.4	27.4
Minn. No. 51 (Parent Variety)	21.6	24.6	20.4	23.3	25.9	30.5	17.6	21.7	23.2

" These varieties were tested as to their flour and bread making qualities with the assistance of Mr. C. E. Foster, of the Consolidated Milling Company, Minneapolis, Minn. Recent tests made by Prof. Harry Snyder also show this to be a very good quality of Blue Stem wheat. It was found to have as good milling and baking qualities as its parent, a hard Blue Stem wheat".

Form 17. Blank Form of Certificate to Cooperators.

Minnesota Experiment Station.

V A R I E T Y   P E D I G R E E   C E R T I F I C A T E.

M I N N. N O. 169 W H E A T.

On ____________, 190_, the Minnesota Experiment Station sold under seed order No._____, to _________________, of variety originated by the Minnesota Experiment Station, and described in Minn. Class Bulletin No. 14.

St. Anthony Park, Minn.

_________________, 190_.

Note: The manner of filling out this blank form for cooperators is shown in A, Table ___.

Form -- Subjoined Blank Form for Certificate to Second Growers as shown in Table ___.

On ____________, 191_, I sold ______ bushels of seed, seed order No.____, raised from the seed described above, to ___________________, of ___________________.

_______________________ Minn.

______________, 191_.

____
Cooperator.

Note: The manner of filling out the blank form in Table___ with the blank form in Table ___ attached, to be supplied by cooperators to second growers is shown in A. and B.

Form -- Certificate as Filled out and Signed -

Minnesota Experiment Station.

VARIETY PEDIGREE CERTIFICATE.

MINN. NO. 169 WHEAT.

On Jan.4, 1902, the Minnesota Experiment Station sold under seed order No. 431 to Harold Powers, of St. Cloud, Minnesota, 4 bushels of Minnesota 169 Wheat, variety originated by the Minnesota Experiment Station, and described under the name "Minn. No. 169" in Minn. Bulletin No. 14.

St.Anthony Park, Minn.
January 4, 1902.

(Signed) W. M. Hays,
Agriculturist.

CERTIFICATE TO SECOND GROWERS

FROM SEED COOPERATORS

On March 12, 1904, I sold 10 bushels of seed, seed order No. ___ raised from the seed described above, to John Lambert of Staples, Minn.

St.Cloud, Minn.
March 14, 1904.

____
Seed Cooperator.

Note: The italic type shows the parts written in by the Station officials, the black faced type shows the parts written in by the cooperator. Each cooperator is expected to keep a serial number of his sales, that each invoice of seeds sold can be traced.

In fact, the tendency is general to yield too early to the impulse to distribute a new variety which gives promise of superior value. The Minnesota experiences, which have erred on both sides in this matter, clearly indicate that promising varieties should be increased just as soon as there is proof that they are promising, but that actual distribution should not be entered upon until superiority over varieties commonly grown is very clearly established. The reputation that the State station distributes only superior varieties which really increase net profits becomes a most valuable State asset. It is important that farmers follow the lead of the station as to the varieties of crops to grow and thus be ready to quickly bring into use varieties proven to add income to the farm. The proportion to follow the station's advice will be in proportion as the station merits and secures their confidence.

The certificate and the bulletin to which references are made containing tabulations showing yields from variety tests, quality from laboratory tests, etc., copies of which may be freely supplied to cooperators for use with their patrons, serves the pedigreed seed grower in advertising so as to secure a market for his crops of seed. It also assists in adding faith and interest better to insure not only the purchase, but appreciative care given the new variety, by the farmer.

The following facts, taken from Bulletin No. 14 referred to in the certificate, served to induce cooperators to purchase the new wheat, and in turn aided them to sell it to their customers.

(See Bulletin 14 and copy from it if deemed wise)

Changing Seeds.

The indiscriminate changing of stocks of grain seeds on the farm often results in changing a good variety adapted to the land to a poorer variety, and sometimes results in the introduction of weeds and plant diseases, while changing to varieties fully tested by competent agencies generally brings increased yields. The value of merely changing from a clay soil to a sandy soil, or *vice versa*, or of changing from the "timber to the prairie", is more often overestimated than underestimated.

That the locality in which seeds are produced does in some instances affect their power to produce good crops, is certain. So little is known, however, of the general principles governing this matter of "place effect", that is, of changing varieties from one soil or locality to another, that growers should move with care. Only where seeds of a known variety from a given locality are known from previous trial to be better yielders in the new locality is it safe first to try them except in a small way. Usually the seeds of good quality produced on other fields of the same farm are to be preferred, providing they are of the best variety. Where unfortunate climatic conditions or other unfavorable conditions have caused the seeds to be very poor, as shrunken, or lacking in viability, changes are often necessary, and where the variety in use is not the best, it is wise to change to the best kind obtainable. The advice of one's own neighbors is usually safe for the seeds for the main part of the crop. But to secure smaller quantities so as to increase them for future use the experiment station and other breeding and variety testing experts should be sought.

In case of field seeds, the farmer can find help from a large number of the State experiment stations, and from the United States Department of Agriculture; and as these institutions increase their work of plant breeding and the testing of varieties, they will have still better information to give in bulletins and in answer to written inquiries.

Cooperation by Neighbors.

In some cases neighbors can cooperate, each one securing a start in seeds of a given kind and sharing the product at a price agreed upon with the others. It is far better that prices, even under these conditions, be kept on a pedigreed seed basis, usually fifty to one hundred percent above market prices for common grain or other commercial product. The larger profit not only places on the grower the responsibility to deliver seeds clean of weeds and disease, also viable and otherwise of good quality, but it keeps the variety on a basis of high valuation where breeding values are given the credit due them. Those who purchase seeds even from a neighbor have an interest in selling good seeds, not alone near home but in the next county, and wholesale lots to the commercial seed merchandising houses. The price should be kept on a pedigreed seed basis until the variety is very generally on the farms of those who will make more profits from the new variety than from the old.

The advice of some of the leading private seed breeders and seed dealers is useful. And especially valuable is the experience of neighbors who have varieties with which they have secured large crops under conditions similar to those for which the new variety is desired. Each farmer must seek all available information in making a change, and broadly choose that variety of which